Gift of

Elaine Gomberg
February, 1984

In Memory of
Her Sister
Judy Joye

MBL/WHOI
0 0301 0083016 2

The Underwater Guide to...

MARINE LIFE

QH
91
.R3
195

CARLETON RAY and ELGIN CIAMPI

The Underwater Guide to . . . . . MARINE LIFE

MARINE
BIOLOGICAL
LABORATORY
LIBRARY
WOODS HOLE, MASS.
W. H. O. I.

A. S. BARNES and COMPANY NEW YORK

© 1956 BY A. S. BARNES AND COMPANY, INC.

All rights reserved. No part of this book
may be reproduced in any form, either wholly
or in part, for any use whatsoever, including
radio and television presentation, without the
written permission of the copyright owner,
except by a reviewer who may quote brief passages
in a review printed in a magazine or newspaper.
Manufactured in the United States of America.

PUBLISHED ON THE SAME DAY IN THE DOMINION OF CANADA
BY THE COPP CLARK COMPANY, LTD., TORONTO

LIBRARY OF CONGRESS CATALOG CARD NUMBER 56-5558

ACKNOWLEDGEMENTS

The comprehensiveness of this book, by its nature, leaves us greatly in debt to several authors and publishers for their help and gracious cooperation in granting permission to reproduce drawings. The figures of plants, chapter 6, were largely adapted from *Marine Algae of the Northwestern Coast of North America* by W. R. Taylor, University of Michigan Press and *Marine Algae of the Monterey Peninsula, California* by G. M. Smith, Stanford University Press. The drawings of sharks, chapter 8, were partly reproduced from Part I of *Fishes of the Western North Atlantic* by H. B. Bigelow and W. C. Schroeder through the courtesy of the Sears Foundation for Marine Research, Yale University, and from *The Plagiostoma* by Samuel Garman through the courtesy of the Museum of Comparative Zoology, Harvard University. Many of the drawings of fishes, chapter 9, were redrawn from *The Fishes of North and Middle America* by D. S. Jordan and B. W. Evermann, a Bulletin of the United States National Museum. The figures of turtles, chapter 10, were based on illustrations from *The Handbook of Turtles* by Archie Carr, Comstock Publishing Associates. Those of mammals were partly based on illustrations from *The Field Book of North American Mammals* by H. E. Anthony, Putnam's Sons.

All of the photographs except two by John A. Moore of Columbia University were taken by the authors with the aid of Russell Kinne. It would not have been possible to procure these photographs without the very kind cooperation of Jim O'Doherty of Robinson-Hannagan Agency, New York, Don McCarthy of the Bahamas Development Board, Nassau, and Abercrombie and Fitch Co., New York, for the loan of the compressor shown in figure 15.

We also wish to thank Peggy and Dennis Hickman of the Pilot House club, Nassau, and their surprised guests who were most understanding when they discovered that we were using their swimming pool as a specimen tank. Nora Wheatly and Jean Wilmot were a great help in the typing of manuscript and the correction of galleys.

The text was improved through the advice of the following: animal behavior, chapter 2, Dr. Helmut E. Adler and Dr. Evelyn Shaw, both of the American Museum of Natural History in New York; photography, chapter 3, Peter Stackpole of Life Magazine; evolution, chapter 5, Dr. John A. Moore of Columbia University; plants, chapter 6, Dr. F. G. Lier of Columbia University; reptiles, chapter 10, Dr. Richard Zweifel of the American Museum of Natural History; mammals, chapter 10, Dr. H. E. Anthony and Dr. J. C Moore, both of the American Museum of Natural History.

CONTENTS

INTRODUCTION ix

SECTION I. *The Sea*

Chapter 1. ZONES OF THE SEA—Where They Live 1
Chapter 2. BIOLOGY OF THE SEA—How They Live 26
Chapter 3. MAN AND THE SEA I—Photography and Equipment 53
Chapter 4. MAN AND THE SEA II—Dangers and Chumming 62
Chapter 5. EVOLUTION, NAMES, AND CLASSIFICATION 68

SECTION II. *Flora and Lower Fauna*

Chapter 6. PLANTS OF THE SEA 76
Chapter 7. THE INVERTEBRATE LEGIONS 86

SECTION III. *Animals with Backbones: the Vertebrates*

Chapter 8. THE LOWER FISHES—Lampreys, Sharks, Rays, and Ratfishes 132
Chapter 9. MASTERS OF THE WATER—Bony Fishes 177
Chapter 10. THE RE-ENTRANTS 303

BIBLIOGRAPHY 323
INDEX 329

INTRODUCTION

The sea for thousands of years has been the least explored part of the earth. Now, with increased interest in the sea and the development of new and growing technology for its study and utilization, great esthetic and material rewards have been made available to mankind. The sea has become for many men a new source of esthetic enrichment because of its primitiveness. It is also a vast reservoir of food and minerals, and this important part of the earth's resources is becoming more so because of the ever-growing problem of overpopulation—a problem which several atomic scientists have called more serious than the threat of the atomic bomb. If the sea is to continue to play its important role in solving this problem, world-wide and local conservation programs must be enacted.

Man's relationship with the sea is the same today as that of the early American pioneers with the undiscovered wilderness. They believed that the land had unlimited productivity. But the rapid consumption of land resources without any thought of conserving the supply has resulted in great decimation of one-time plentiful forests and wildlife. Even James Audubon did not believe that the passenger pigeon of our plains, formerly one of the world's most numerous birds, could ever become extinct. Flocks of millions once filled the skies, yet today not one remains. Similar stories of decimation have been repeated in the cases of the American bison, pronghorn antelope, bighorn sheep, beaver, many species of ducks, and valuable timber trees such as southern long-leaf pine, sugar pine and several hardwoods. These examples are only a small fragment of a long list of man's abuse of the land.

We must avoid the careless and tragic exploitation of the sea which we have not avoided in the case of the land. Behind this exploitation lies one of the commonest beliefs of modern man—that the sea is inexhaustible. It is absolutely vital to realize that the sea, like the land, has its limits and that the exploitation of the sea beyond its ability to replenish itself can only result in the situation that exists on much of the land. Already there are signs of the exhaustibility of the sea. Whales, thought to be innumerable at one time, were so scarce before World War II that many whaling fleets ceased operations. Since the war, international control has resulted in a slow increase in their numbers. Sea otters, fur seals, sea turtles, striped bass, salmon, shad, and others all were, or still are, exceedingly important economically and have all suffered severely from exploitation. Commercial catches of many important species of schooling fishes are

smaller today than previously in spite of the introduction of scientific fishing methods.

The sea is also used as a gigantic dumping ground for industrial chemicals, sewage, garbage, oil, and atomic wastes. There is a widespread feeling that these things thrown into the sea are safely and completely disposed of. But they return to plague us in the form of reduced commercial fisheries, exterminated game fishes, littered beaches, poisonous shellfish, and polluted waters. For example, several New England rivers at one time had runs of Atlantic salmon which compared favorably with the runs of Pacific salmon on the west coast, but now, because of overfishing and pollution, there are few salmon south of Maine.

These are the abuses that conservationists work to prevent in order to maintain the long-term esthetic and economic resources of the earth. Conservationists are not the wide-eyed dreamers they are frequently thought to be, interested merely in preserving remnants of rare fauna and flora. Although preservation of rare species is part of conservation, they are mainly concerned with the theme first popularly advocated by Theodore Roosevelt—"conservation through wise use."

There are two basic concepts pervading the philosophy of western man that have been serious barriers to the development of a realistic conservation program. The first is the economic conviction that the only possible healthy economy is one which is constantly expanding—more and more production with little thought given to resource limits and replenishment. Second is the primarily theological dualistic view of the world wherein man and nature are somehow separated—man rules the world by a sort of egotistical "divine right of kings." Both of these concepts are in direct contradiction to the known facts that man and nature are one and that man cannot abuse nature without harming himself in turn.

> I do not see a planet concreted over its land surfaces to provide living and factory space for an immense human population nourishing itself and supplying all its needs synthetically. Human life is going to depend on plant life for a long time yet, and in far more ways than its value as an efficient conversion agent . . . man is still adolescent as a conscious species and he is faced, again in full consciousness, with the choice of whether he shall mature into a species loving his world or remain irresponsibly wielding his new toy of an expanding economy.
>
> F. Fraser Darling
> *American Scholar,* Winter 1956

* * * *

Spearfishing and Skin-diving: A Program for the Future

> Such is oftenest the young man's introduction to the forest, and the most original part of himself. He goes thither at first as a hunter and fisher, until at last, if he has the seeds of a better life in him, he distinguishes his proper objects, as a poet or naturalist it may be, and leaves the gun and fishpole behind.
>
> H. D. Thoreau — *Walden*

We have noticed a gradual transformation in some divers which involves a change from a spearfisherman to a naturalist, photographer, or explorer. As the spearfisherman moves about the reefs looking for his prey, he becomes aware of the beauty and variety of marine life. It soon becomes unimportant whether or not he spears anything. His reward is in viewing nature and in gaining an understanding of it and of himself. He also gains an appreciation and respect for the order of things in nature and develops a feeling for not wanting to disturb it.

Uncontrolled spearfishing, on the whole, has the two major disadvantages of rapidly depleting the number of fishes in an area—even more rapidly than the net or hook in most cases—and of driving fishes that are not killed into hiding at the sight of man. It doesn't take long for a diver to recognize an area where spearfishermen have been. There is an air of desolation as evidenced by the empty reefs, and the few large fishes that are present are exceedingly wary. In sharp contrast, reefs which have not been invaded with spears have yielded some of our most interesting experiences underwater. Most of the fishes show little fear and have given endless opportunities for study of their fascinating behavior and for photography. The same contrast exists between areas where the over-enthusiastic shell or coral collector has been and those reefs which are untouched and unbroken.

We feel there is a definite need for a program which will maintain and conserve marine life so that it will not be depleted beyond its ability to replenish itself. Only through a sound conservation program can skin-diving, either for esthetic or sporting values, be maintained as an expanding and long-range activity. A reef can not be cleaned out of fishes in one summer and be expected to have replenished itself the following year. It takes some species many years to reach maturity and large size and if the sport diver wants to see fish, he can not take them without any thought of conserving the supply. We suggest the following program:

1. Underwater Parks

Some of the richest areas should be set aside and protected as are "wilderness" areas on land. The taking of any marine life, animal or plant, by any means, should be prohibited. The areas selected should be distributed widely so that they could act as reproductive centers from which non-protected areas would be replenished with life. These areas would be open to skin divers, naturalists, photographers, and all those who come to enjoy the wonders of nature. The benefits derived from undersea wilderness areas are as follows:

a) Areas of replenishment. Game and commercial fishes can replenish their numbers and stock non-protected, surrounding areas, insuring a constant supply. This guarantees continued and growing interest of sportsmen upon whom large sporting industries and tourism are dependent.

b) Sanctuary. Common and rare species would be protected from extinction.

c) Esthetic values. The natural, virgin beauty of sea gardens unspoiled by broken corals or fishes made scarce and wary by spearing is preserved. Interest in natural beauties of the sea is maintained and expanded and these areas would become valuable tourist attractions.

d) Science and education. Parks serve as natural outdoor laboratories for accumulating knowledge of the sea, for investigating methods of increasing fisheries' productivity, for formulation of better conservation policy, and for basic scientific research.

2. Regulation of Spearfishing

The pressures on fish populations exerted by increasing numbers of spear fishermen have rendered many areas not worth visiting by the sightseer or spearfisherman. *Controlled* spearing, however, will not diminish the population of an area because it serves to take off some of the individuals that would normally have died of natural causes.

a) Licensing. Spearfishermen should be licensed in order to maintain control. Funds derived should be used solely for conservation and enforcement.

b) Regulating catch. Game fishes should be designated and for each of these, season, bag, and minimum size limits should be established. The spearing of small, non-game fishes such as angelfishes, butterfly fishes, etc., should be prohibited.

c) Designation of areas. Spearing should be restricted to outlying areas because, in general, spearfishermen are better divers than sightseers are, and because any amount of spearing tends to make fishes become wary or drive them off to deep waters. This would leave easily accessible waters for non-spearfishermen such as skin-divers, sightseers, naturalists, and photographers.

Whether our inshore waters remain filled with life and a source of enjoyment for present and future generations, or, whether they go the way our now comparatively barren forests and plains have gone, depends upon the instigation of a conservation program immediately.

How to use this Book

This book is divided into three sections. The first section consists of chapters on the sea as an environment for life, how life adapts to this environment, dangers that exist in the sea for man, underwater photography, and evolution. These chapters are included in order that the reader will better understand the sea and its life and should be read before attempting to identify species or groups or to interpret behavior. The last two sections are a guide to the identification and habits of groups of marine plants, invertebrates, and vertebrates. Because of the huge numbers of species in the sea (400 basses alone, for instance), each group (family, order, etc.) is represented by only a few of its commonest species which characterize the group as "types." Therefore, the reader will not always be able to identify a particular species with this book, but, by becoming familiar with the characteristics of a group, he can categorize any species of that group he may come across anywhere in the world. Thus, the ulua of Hawaii can be identified as a species of jack, the merou of the Mediterranean as a grouper, and Japan's tai as a porgy. Identification of groups is made by characteristics recognizable in the field—silhouette, pattern, movement, etc.—and not by laboratory methods such as fin counts or fine anatomy. Though this book emphasizes groups rather than species, it is important that the reader refer to a particular species in his observations of behavior.

All of the species given as examples of groups are found in North American

waters chiefly over the continental shelf. Many of the species given, however, range to deep waters and beyond North American seas. Many of the pelagic species are world-wide in distribution.

Because of the tremendous scope of the subject of the sea, the reader is asked to refer to the bibliography for detailed information.

There is a great body of unknown facts that only the swimmer can procure because of his intimate contact with the sea. In 1933, Beebe and Tee-Van wrote that ". . . not one complete life history of a Bermuda fish is known." That statement is largely true today of marine fishes everywhere. This guide has been written in response to the growing interest in the sea and its life in the hope that better knowledge of the sea and its relationship to man will result.

Carleton Ray and Elgin T. Ciampi
April, 1956

SECTION ONE

The Sea

CHAPTER 1

ZONES OF THE SEA—Where They Live

The study of mankind—his behavior, his diseases, his history—could not progress very far nor be very meaningful if careful attention were not paid to his environment—where he grew up and under what circumstances, the climate, culture, geographical location, and economic conditions. The same is true of wild life. Whatever aspect we care to study, scientific or aesthetic, a consideration of the environment must enter our minds. If one tries to imagine a plant or animal without environment, it becomes almost impossible to obtain much insight into its nature, whether it be a one-celled animal or a complex animal such as man. For instance, the odd shape of a sargassum fish has little meaning by itself, but when it is viewed from the perspective of self-preservation in its habitat of sargasso weed, its meaning as a concealing, protective form becomes clear.

The study of the relationship between life and its environment is scientific natural history or ecology. Ecology might be called the crossroads of the life sciences, where such fields as genetics, paleontology, anatomy, physiology, embryology, animal behavior, oceanography, evolutionary study, and others find common ground. But let none assume that ecology is for the scientist only. The diver who has learned to associate groupers with their homes in coral or rock has made an ecological observation.

Ecology is the subject of the first two chapters of this book in the hope that as insight into the sea's environment increases, so will our ability to appreciate the beauties and wonders of the sea increase. In this chapter the main characteristics of the sea and its zones will be given. The ways and means that life has adapted to this environment will be discussed in the chapter which follows.

EARTH AND THE SEA

The perspectives and visions of mankind are often not as broad as we would like to believe. Much of the narrowness of man's particular world is a consequence of the evolutionary place he has come to occupy—that of a giant land

animal. His size has made it extremely difficult for him to project himself into the worlds of the small living things that swarm about him and has restricted his vision to include mostly the forms of life that are, like him, giant.

His terrestrial point of view has caused him to make a fundamental mistake in his conception and naming of the planet on which he lives, for this planet is not one characterized by dry land nearly as much as by the sea. No other planet, as far as is known, has a sea. Had man been aware of this from earliest time, he might well have named this planet "Sea" rather than "Earth."

The sea is not only the most unique characteristic of earth, but it clearly dominates the land in surface area covered. About 70 per cent of the earth's surface is covered by the sea, an area encompassing about 139 million square miles. By contrast, all of the lakes and rivers add up to only about one million square miles. The sea averages about two and one-half miles in depth, whereas the land rises an average of only slightly more than four-tenths of a mile above sea level. The volume of sea water is about 334 million cubic miles, a volume so great that it has been estimated that if all the earth were made level, the sea would everywhere cover it to a depth of one and one-half miles!

PHYSICAL FACTORS OF THE SEA

Water

The remarkable compound to which all life is responsible and which gives the sea most of its important characteristics is water.

First, water is most common on earth in its liquid state, and it is fortunate that the temperature range of most of the earth lies between water's freezing point and boiling point, that is, between 32° and 212° Fahrenheit (salt water freezes at about 29°). It is not merely happenstance that the temperature limits of life lie between the temperature limits of liquid water.

Second, water is one of the few compounds that expands, becoming less dense, when it changes from the liquid to the solid state. This enables ice to float, a fact of the greatest significance, for if ice sank, the depths of the sea, and eventually the whole of polar seas, would freeze solid.

Third, water is the most universal of all solvents, able to dissolve large amounts of a wide variety of substances that are absolutely necessary for life. In fact, protoplasm is 50 per cent (flour beetles) to 98 per cent (jellyfish) water. This liquid virtually bathes every fiber of living bodies, carrying food and oxygen to cells and carting off metabolic wastes such as carbon dioxide and urea.

Fourth, water has a very high capacity to store heat. The great body of ocean water is the storehouse of the earth's heat. Without the oceans, the dark side of our planet would come close to freezing nightly.

Fifth, water is dense and gives support and buoyancy to the animals that live in it. This has the important consequence of solving the problem of support for marine animals. Strong legs, arms, and skeletons, necessary for support on land, are lacking in the sea. Instead, the bodies of marine animals are modified for locomotion and for offense or defense, and not usually for support. Plants in the sea have no strong supporting stem or trunk. Because of water's buoyancy,

many marine animals attain large size. Whales reach measurements that are impossible on land; if they themselves are beached, they are unable to breathe because of the great weight of their own bodies.

Dissolved Salts

For all of its remarkable qualities, pure water would not afford much of a home for living things. The salts are the fertilizers of the seas, and without them animals and plants could not grow. The seas of the world average about 35 parts per thousand of salt with extremes of 15 parts per thousand at the poles, where melting ice dilutes the waters, and 46.5 parts per thousand in the Red Sea, where there is a high evaporation rate and practically no dilution by rivers. Most of the salts are sodium chloride (table salt), potassium chloride, and magnesium chloride, but these are not the really vital ones.

Nitrogen is vital in the building of protein. It is rather odd that animals and plants are not able to utilize atmospheric nitrogen, even though nitrogen composes about 80 per cent of air. That task falls to the incredibly numerous nitrifying bacteria in the soil of land, which manufacture salts called "nitrites" and "nitrates" from the nitrogen of air. These are then used by plants to build protein. Eventually, however, many of these nitrites and nitrates find their way into the sea by way of river systems. Allee, and others (1950) estimate that the Mississippi River alone brings 792,000 tons of nitrate into the Gulf of Mexico each year. This is the principal but not the only way that nitrogen reaches the sea. Some nitrifying bacteria exist in shallow sea waters, but how much they contribute is not known.

Once in the sea, nitrites and nitrates are used by plants in the so-called shallow-water "zone of nitrogen utilization." Animals eat the plants, and nitrogen in the form of protein is distributed in the tissues of living things of the sea. When these things die, they sink to the depths. Bacteria cause decay, and nitrogen compounds are released in a deep-water "zone of nitrogen regeneration." Nitrites and nitrates accumulate in the depths until they are swept to the surface by currents in places where upwelling occurs. On the surface this rich fertilizer once again becomes available to plant life. So we see that nitrogen in the sea, is subject to an endless cycle, a cycle intimately connected to that of life and death.

The story of that other important fertilizer, phosphorus, is similar to that of nitrogen. Once again, it is brought from the land to the sea by rivers, and again it is used by plants in a zone of phosphorus utilization. The plants are eaten by animals. These living things sink to the deep sea when they die. Decay releases phosphates in a zone of phosphorus regeneration and upwelling of deep waters brings them to the surface.

Immense as are the amounts of nitrogen and phosphorus compounds in the sea, we must not think that they are inexhaustible. Just like any other fertilizers, they can be used up. Every summer, as the sea warms and the plankton turns the sea into a living soup, these fertilizers become progressively scarcer as the abundant life uses them up. In some places the amount of such fertilizers limits the amount of life that can grow in the water. When cold weather returns, much of this life dies and the fertilizer returns to the depths. So the cycle of

nitrogen and phosphorus is one of the seasons as well as of life and death.

Calcium is an important substance in the life of the sea but for a different reason than was the case for nitrogen and phosphorus. It is also brought to the sea by fresh water, existing in sea water as calcium sulfate largely, but it does not build tissues. Instead, it builds skeletons. About 1.6 per cent of the salts of the sea are calcium compounds. Many groups of animals, notably corals, sponges, crustaceans, worms, molluscs, foraminifers, and some coralline plants are able to precipitate soluble calcium compounds into relatively insoluble calcium carbonate to build their skeletons. Since this reaction proceeds fastest at about 75° to 80° Fahrenheit, a common temperature range for tropical waters, it is no surprise that coral reefs and the largest shelled animals are found in the tropics.

Silicon is similar to calcium. It is a skeleton builder, but it is used by only a few groups, notably radiolarians, diatoms, and sponges. It exists in the sea in the form of silicates. Silicates are the principal component of common glass, and most siliceous skeletons have a decidedly glassy look.

Nitrogen, phosphorus, calcium, and silicon are the four biologically most important elements that are present in the sea in the form of dissolved salts. There are other elements of lesser importance, such as iron and magnesium, with similar case histories.

Aside from their importance to life, salts have two important effects on water. One is that they depress the freezing point of salt water from 32° Fahrenheit to about 29°. The other is that salts cause water to be more dense. Various salt concentrations are partly responsible for varying water densities.

Every year about 660 million tons of earth are washed into the sea, and with this dirt come great quantities of nitrogen, phosphorus, calcium, and silicon. Therefore, it would seem that the sea is constantly growing more and more salty. Some scientists have assumed that the sea was originally fresh water and have even tried to compute the age of the sea by dividing the total tonnage of salts in the sea by the yearly deposition rate, but they have arrived by this method at very low figures for the age of the sea. The reason for this is that deposition of these salts in the sea occurs at a varying rate, and salts are often deposited permanently on the bottom. As salts are added by rivers, so they are taken out of the water by various means. In fact, the sea has probably remained about as it was with respect to salt content for the last billion years.

There is some correlation between river deposits of salts and abundance of life. The Atlantic and Arctic receive most of the North American river drainage and have continental shelves to hold the deposits. Less river water flows into the Pacific, it has no shelf to speak of. The comparative richness of life in the Atlantic is due to this fact. The richness of some Pacific areas is due to another factor, upwelling.

Dissolved Gases

Oxygen enters the sea primarily by being dissolved at the water's surface and is distributed by water currents. Disturbed surfaces dissolve oxygen best simply because more surface is exposed and because rough water acts as a good mixing agent.

Plants also furnish oxygen to the sea by the process of photosynthesis. This reaction requires light, however, so it occurs only in approximately the first 250 feet of water. As the light diminishes with depth, plants become oxygen users, not producers. At about 100 feet, plants use about as much oxygen as they release, and below that depth the few plants that exist become dependent upon oxygen, releasing very little. The 100-foot depth is called the "compensation level," and it varies with light conditions, latitude, time of day, and water clarity.

Oxygen is extracted from water by the respiration of all forms of life and by oxidation and decay of dead bodies through the agency of bacteria. Allee, and others (1950) state that bacteria probably use more of the sea's oxygen than all other forms of life combined.

The concentration of oxygen in the sea is highest at the surface, where solution and photosynthesis take place and where the water may even become supersaturated. This is particularly true of brightly lit surface waters in mid-afternoon when photosynthesis is at its peak. At a depth of about 1,500 feet, oxygen falls to its lowest level because it is not produced there, yet enough life is present to use what there is rapidly. Oxygen increases below the 1,500-foot level because it is carried downward by sinking cold waters from polar seas.

In the comparatively few deep spots where overturn of water cannot occur and where sinking cold water cannot reach bottom, the water may become stagnant. All of its oxygen is used, and the poisonous gas hydrogen sulfide accumulates from the decay of dead bodies that sink there. The Black Sea is the most famous body of water that accumulates hydrogen sulfide. Practically no life at all occurs there from a depth of 600 to 6,000 feet. The Bay of Naples and several deep fiords of northwestern Europe also tend toward stagnancy.

Carbon dioxide is the third major gas in the sea. It is a fertilizer similar to the salts of nitrogen and phosphorus. It is released into the sea by the respiration of all animals and by plants deprived of light. It is dissolved by surface waters in the same way that oxygen is dissolved from the atmosphere. It is also released at the bottom of the sea by decomposition of dead bodies and, like nitrogen and phosphorus compounds, accumulates in deep waters. Upwelling brings this carbon dioxide to the surface.

Carbon dioxide is used in two very important ways. First, it is used by plants in photosynthesis to build carbohydrates (sugars and starches). Second, it is used in the converted form of carbonates and in combination with calcium to build the limy skeletons of many invertebrates.

Pressure and Depth

Next to the wetness of water itself, the most noticeable effect of water on the diver is that of increased pressure as he descends. The pressure of air at sea level is one atmosphere or about 15 pounds per square inch. For every 33 feet of descent into the sea, the pressure increases one atmosphere. At the deepest part of the ocean, animals are subject to about 1,000 atmospheres of pressure or 15,000 pounds per square inch. This immense pressure would be quite disastrous if applied unevenly to a body, but it has no effect when it is exerted in all directions inside the body and out. To illustrate: each square inch

of our body is subject to 15 pounds of pressure at sea level. Yet we feel nothing. The pressure outside us is balanced by pressure in our tissues. However, if the pressure were exerted unevenly, there would be a startling difference. The area of the palm of a hand is about 10 square inches. Very few of us could move our hands if they were held down by 150 pounds of weight. At a depth of 100 feet this weight would become 600 pounds. But, as many aqua-lung divers know, there is little difference in swimming at 100 feet or near the surface because the pressure is equal in all directions inside the body and out. This is not to say, however, that dives to 100 feet are as simple as those at the surface.

Pressure at any depth is due to the weight of water in a column above that depth. As is well known, added weight on a body will tend to compress it, but water is not very compressible. If water were incompressible, the surface of the ocean would rise about 100 feet, but 100 feet in an average depth of two and a half miles is a very small fraction. This comparative incompressibility of water has the effect of keeping buoyancy about the same at all depths, so that incompressible objects sink in the sea at an even rate all the way to the bottom. Compressible objects, such as fishes with a swim bladder, would tend to sink faster and faster with increased depth since added pressure reduces their volume which, in turn, decreases buoyancy. To combat this, fishes increase the pressure in their swim bladder to keep their body volume constant and to equalize buoyancy at all levels where they swim. The depth to which any fish can safely descend might depend in part on its ability to increase pressure in its swim bladder to match water pressure. Hesse, Allee, and Schmidt (1951) state that surface fishes with empty swim bladders can stand pressures of 100 atmospheres without harm.

Plankton is similar to fishes in being able to withstand rather drastic pressure changes. By day, much plankton lives just at the edge of the lighted sea, at a depth of 1,200 to 1,500 feet. By night, this plankton rises to the surface, a change of 30 to 40 atmospheres of pressure, without harm.

Though very little is known about pressure relations in the deep sea, one thing seems fairly certain. The pressure itself plays a relatively minor part in determining what forms of life live there. More important are temperature, which is near the freezing point in the deep sea, lack of light, and relative scarcity of oxygen and food. But pressure does have special effects to which animals must adapt. The swim bladder problem is one that deep-sea fishes must solve. Pressure also causes colloid gels (such as protoplasm) to take on more water, and for this reason deep-sea animals are more gelatinous in texture than shallow-water ones.

Light

Light is important to life in several ways. First and foremost, it supplies the energy necessary for plant photosynthesis. Second, it is necessary for sight, without which the behavior of many forms of life would be radically changed. Third, it is responsible for color itself and for the adaptive coloration of animals and plants.

The nature of light and color are vitally important concepts to grasp if we

are to understand the way animals and plants live. Light as we see it is actually composed of a mixture of colors: red, orange, yellow, green, blue, indigo, and violet. These spectral colors have been seen by anyone who has seen a rainbow or looked at sunlight refracted through a prism. These colors take the form of waves of varying length. As the length of the waves varies, so does the color of the light vary. The longest visible wave lengths are red and the shortest are violet. Light waves that are invisible to our eyes exist, and these are called "infrared" (longer than red) or heat waves, and "ultraviolet" (shorter than violet) or burning rays.

Light has two important characteristics that are important to the photographer (Chapter 3) and to the life of the sea. These must be distinctly separated in the mind as two factors which may act either separately or together. They are *intensity* and *quality*.

Intensity simply means brightness. Any wave length or combination of wave lengths can exist over a wide range of intensities. As progress into the depth of the sea is made, intensity of light decreases. Some animals have photoreceptors that react solely or chiefly to light intensity. Intensity regulates the behavior of a great number of animals. Some plankton rises to the surface by night. Squirrel fish, conchfish, coral polyps, and big-eyes become active at dusk. Plants cannot photosynthesize below a certain light intensity.

Quality of light, or color, depends chiefly on differences in wave length from red to violet. The color of an object depends on differential absorption of some wave lengths of light and the reflection of others. For example, the squirrel fish appears red because it absorbs all wave lengths of light except red, which it reflects. Quality of light has important consequences for life. The different groups of algae photosynthesize in response to different wave lengths. Adaptive coloration of many animals is a response to light quality.

It is now possible to descend from the surface to the abyssal depths of the sea and to see what happens to light as progress is made downward. The most immediate effect of sea water on light is reflection from the surface. In calm waters about 3 to 4 per cent of light is reflected and never enters the sea, in average waters 15 per cent, and in rough waters about 30 per cent.

From the surface to depths, the quantity of light diminishes constantly due to the opacity of water. It is possible to divide the sea into three zones on the basis of light intensity alone.

1. Euphotic or Well-Lit Zone. This is the shallow-water zone with a depth range of about zero to 250 feet. It is rich in plankton, especially the photosynthetic types, and in herbivorous or plant-eating animals. Photosynthetic plankton is abundant to 150 feet and almost disappears at the deepest part of this zone. The depth of this zone is largely determined by the water's clarity. The Sargasso Sea is probably the clearest sea water found anywhere. Sea water is generally more transparent than fresh water.

2. Dysphotic or Dimly Lit Zone. From 250 feet to the level at which all light disappears, the life of the sea is adapted to dim light. The level at which all light disappears varies from 600 feet to about 5,600 feet depend-

ing on water clarity and the angle of incident light. The extent of this zone is not as deep near the poles as near the equator. Animals of this zone frequently have large eyes in order to be able to see in weak light. Animals with bioluminescence, that is, possession of organs that can emit light, become common. Herbivores, or plant-eating animals, become scarce or absent. In clear water, the intensity of light at 3,000 feet is one three-millionth of its intensity at 3 feet.

3. Aphotic or Lightless Zone. Below the dysphotic zone, no light at all exists. Many, if not most, animals possess luminescent organs, either for food-finding or defense. Eyes may be totally lacking or reduced in size. Herbivores are completely lacking, and only detritus eaters (those who eat debris) or carnivores are left.

Quality of light is also affected by water, but there are no zone names to describe this. In clear waters, the long waves or reds are absorbed first and the short waves or violets are absorbed last (Chapter 3). Silty or plankton-filled waters reflect red and yellow and therefore appear greenish. By the use of colored photographic plates exposed for long periods, it has been determined that all wave lengths are still present in clear water at 300 feet, but the reds are exceedingly weak. At 1,500 feet red and green are gone completely. William Beebe, in his dives in the bathysphere, observed that a strangely bright, blue light could be perceived by his eye up to about 1,800 feet. After that he saw no light at all. Blue light not visible to the human eye persists quite a distance below this depth, however.

The colors of animals and plants vary in response to these changes in light quality. It is not nearly as difficult to correlate the color changes in plants with depth (Chapter 6) as it is to correlate these changes in animals. For instance, it is well known that many nocturnal animals are red (squirrel fish, big-eye, etc.) and that animals of the dysphotic zone where red is lacking tend also to be red (especially fishes and crustaceans). At those depths these animals must appear black since there is no red left to reflect. Red animals give way to brown, black, or transparent animals in the aphotic zone. So it would appear that red coloration is an adaptation to dim light or to waters where red wave lengths are lacking and that it acts as protective coloring for these animals of nocturnal habits or dimly lit zones. Many people have wondered why so many animals are red at depths where red supposedly cannot be seen. The assumption is made that animals see as humans do. But many animals that live in waters of low light level have the capacity to see objects that humans cannot see. To these animals, red objects are protectively colored.

Temperature

Temperature determines to a very important extent where and how animals live. Sea water varies from 27° to 108° Fahrenheit depending on latitude and depth. The temperature of surface water varies the most, but deep water of over 1,000 feet in depth in all latitudes is extremely uniform at about 35° Fahrenheit. Temperature variation is not nearly as great anywhere in the sea

as it commonly is on land. Rarely does the sea vary more than 70° Fahrenheit at any one place. By contrast, land temperatures at Fairbanks, Alaska, vary from 60° below zero in winter to 105° in summer.

If a diver were to progress downward through the water, even in warm seas, he would reach, at a depth of 150 to 500 feet, a level where the water suddenly became much colder. This place is called the "thermocline" and marks the strong stratification between warm surface waters and cold deep waters.

Temperature has several effects on water and on animals which are purely physical. Cold waters are denser and have a greater viscosity than warm water. Cold waters, therefore, sink below warm waters, and the temperature differences become partly responsible for water movements in the ocean. Increased viscosity of cold water means that planktonic animals sink more slowly in cold waters than in warm. This may be part of the explanation for the huge concentrations of plankton, particularly crustaceans, pteropods, and protozoans, in arctic or subarctic waters or in deeper waters of warmer seas. These planktonic animals are relatively scarce in shallow, warm waters.

Features of the Sea

It is easy to imagine the sea as a sort of featureless bowl, but since the advent of sonic soundings about fifty years ago, it is now known that the seas show all the features of the land—mountain ranges, canyons, valleys, volcanoes, etc. There are differences between the features of the sea and those of land, however. The former are on a much grander scale but are barren and comparatively immutable. The gigantic deformities in the suboceanic crust of the earth for the most part lurk in dark, silent, plantless depths, where erosion is almost at a standstill.

Geologically speaking, the ocean may be divided into three regions (*fig. 1*):

1. Continental Shelf. This is a gradually sloping extension of the land under water. It is formed by the deposition of river sediments as they are brought from the land. As the ocean's water level rises and falls, the shelf is alternately part of the underwater sea and part of the land. In some places, such as the West Coast of North America, no continental shelf to speak of is present, but the edges of most continents have shelves extending outward from shore as little as 10 or as much as 800 miles. The edge of the shelf is usually at a depth of 600 feet. The shelf fauna and flora is the most varied in the sea.
2. Continental Slopes. At the edge of the continental shelf the downward pitch of the ocean bottom increases rapidly so that the water gets rapidly deeper. These clifflike slopes and escarpments form intermediate depths of the sea where protozoan oozes cover most of the bottom (Chapter 7). The size of these escarpments so dwarfs anything of similar form on earth that it is hard to comprehend them. They may descend from 600 to 18,000 feet, taking 100 miles of downward slope to do so. This represents a maximum size, but in some places the escarpments are even more spectacular, being not as long but much steeper.

3. The Deep-Sea Bottom. This lies below the great majority of the sea's area. It is here that the most spectacular canyons on earth sink and the greatest mountains on earth rise.

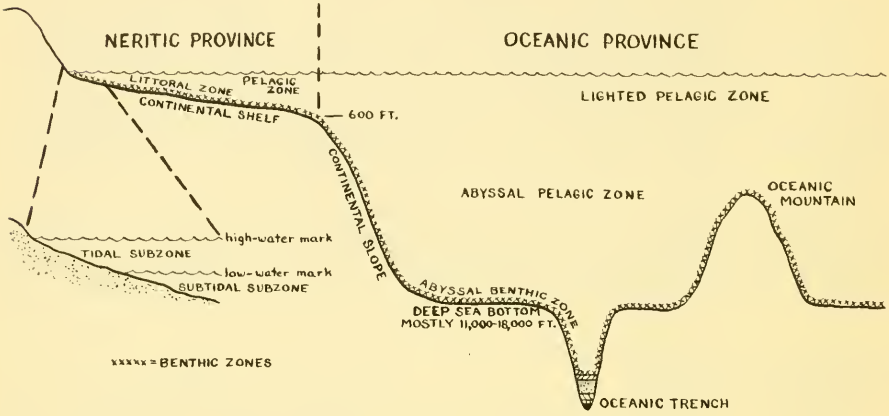


Fig. 1. Features and zones of the sea.

In the western United States are many well-known mountains, one of which is Pike's Peak. It rises to 9,000 feet from a plateau of 5,000 feet high, a total of 14,000 feet. Mt. St. Elias in Alaska is one of the very largest of mountains on earth, rising from sea level to 18,000 feet, twice the height of Pike's Peak. Mt. Everest rises to over 29,000 feet, but its base is very high, so it actually is not as large in sheer volume as is St. Elias. By contrast, Mauna Kea of Hawaii rises a total of 31,000 feet directly from the sea bottom (almost 14,000 feet from sea level) and is so huge that it forms the greater part of the largest of the Hawaiian Islands. There are many huge mountains under the sea at least as large as Pike's Peak that never even reach the surface.

Mountain ranges of the sea are no less spectacular. By far the longest range on earth is undramatically called the "Mid-Atlantic Ridge," which is 10,000 miles long. It begins off the coast of southern Africa and runs unbroken to Iceland, showing a few times above the surface in such islands as the Azores and Ascension.

Perhaps the most spectacular and mysterious of the deep-sea features are the trenches, steep canyons usually found close to shore lines and continental shelves, which plummet to depths of up to 35,000 feet (Mariana Trench). The deepest North American trench is the Puerto Rican Trench with a depth of 30,246 feet. Trenches are usually deeply filled with layers of sediment a mile or more in thickness. Without these, the trenches would be even deeper.

The bottom of the deep sea is usually covered with a monotonous layer of red clay where a few hardy animals make their homes. Hesse, and others

(1951) give the following percentages for the distribution of the depths of the seas over the earth.

15.6	per cent of the sea bottom is 0–5,900	feet deep
19.3	" " " " " " " 5,900–11,800	" "
58.4	" " " " " " " 11,800–17,750	" "
6.5	" " " " " " " 17,750–35,600	" "

The Movements of Water

This is a complex subject which concerns waves, tides, horizontal water currents such as the Gulf Stream and vertical currents such as upwelling. It is very difficult to clearly separate these factors. All of them cause a mixing of ocean water in complex patterns and are thus vital to the life of the sea, particularly in distributing animals and plants and in fertilizing surface waters from below.

Waves constitute the least massive of the various types of water movement. They are surface phenomena, rarely having any effect on waters greater than 300 feet (or a maximum of 600 feet) deep.

Winds provide the energy necessary to create a wave. The size of a wave depends mainly on four factors of winds: (1) velocity—the stronger the wind the higher the wave, (2) duration—the longer the wind blows, the higher waves will become, (3) fetch—the longer the distance over water that the wind can blow without obstruction, the larger the waves, and (4) direction—the longer the wind blows in an unchanging direction, the bigger the waves will be. These four factors interplay and vary greatly to produce waves of a few inches high to a probable maximum of 40 feet in height. Barnett (1954) states that it would take a 60-mile gale blowing steadily in one direction for a distance of 900 miles to produce a 40-foot wave, and since such conditions are not often met, such waves are rare. The very high velocity of gusty winds does not produce high waves because it literally blows the waves' tops off.

The water itself moves very little in the horizontal direction of the wave. It merely rises and falls in a circular fashion as the wave form passes through it. To prove this, all one has to do is to place a floating object on the water's surface and notice that it bobs up and down in a circular pattern with the waves, but does not move forward with them. When a wave reaches shallow water, the circular pattern of the water movement becomes flattened because of the proximity of the bottom. This causes the forward edge of the wave to become steeper and steeper until it falls over on top of itself and breaks (*fig.* 2). The force of a breaking wave can be tremendous. It is enough to carve holes in rocks or to lift large stones and even throw them through the air. It has been calculated that some huge waves strike with a force of up to 3 tons per square foot, ample warning that swimming in large breakers near shore can be very dangerous business.

Tides are very different from waves, in that they are of cosmic origin. The gravitational pulls of the sun and the moon provide the energy of the tides. When the sun and moon are both lined up with the earth and with each other,

their pulls are complementary and the highest tides, called "spring tides," occur. This happens during the new and full moons. When the sun and moon form a right angle with the earth as the center, their gravitational pulls partly cancel each other and the lowest or "neap tides" occur. This happens during the first and third quarters of the moon.

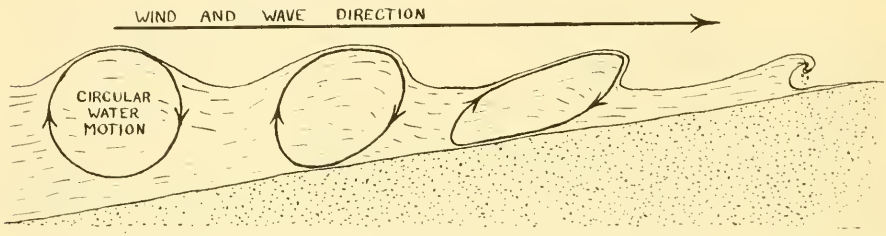


Fig. 2. The breaking of a wave on a sloping shore.

Tides are erratic in occurrence and in height. In general they are lowest at the equator and highest toward the poles. In most places high tides occur twice a day, but in some places they occur only once. The highest tides in the world occur in Nova Scotia's Bay of Fundy, followed closely by several spots such as the Turnagain Arm near Anchorage, Alaska. In both of these places, tides must travel up narrow channels in a short period of time. This causes a tidal-wavelike rush of water called a "bore" to form. It is not known exactly why extremely high tides form in some places and not in others. Presumably it has to do with the configuration of the ocean bottom. If the bottom forms a trough, so that water can oscillate back and forth in it like water in a bathtub, and is the right size, so that the period of this rocking vacillation matches the period of the movements of the sun and the moon, water will rock back and forth in the trough to give very high tides of up to 50 feet. Bores will occur when the trough has a constricted end, up which tidal water may rush.

The currents in the sea have a more complex origin and are of greater importance than waves and tides, even though they are usually not as spectacular to look at. Horizontal currents traveling over the ocean's surface are motivated primarily by prevailing winds, and their direction is influenced by the rotation of the earth. The prevailing winds in both hemispheres blow from the east along the equator, the trade winds, and from the west along the horse latitudes (30° north and south), the westerlies. The rotation of the earth causes a deflection of these winds so that their paths become circular—clockwise above the equator and counterclockwise below. In general, ocean currents follow this wind pattern (*fig.* 3), but are complicated by the conformation of coasts and the ocean bottom. In the center of these great, rotating bodies of water are eddies where the water just turns around and around and never goes anywhere. One such eddy is the Sargasso Sea.

Vertical currents are caused by density differences of water, that is, by varying temperature and salinity. As water is heated near the equator, it becomes

less dense, rises to the surface, and flows northward. At the polar regions, it cools, sinks and flows very slowly back to the equator at the rate of a mile a day. In warm seas, water evaporates rapidly and becomes denser due to increased salinity. In the Sargasso Sea, for instance, water sinks due to increased salinity. Tropical rains have an effect in diluting water and making it less dense. These interplaying factors vary so as to produce quite complex results, but temperature has generally the greatest effect in the oceans. Thus, circulation is mostly toward the poles on the surface and toward the equator in deep water.

Upwelling is a special and very important vertical movement caused mostly by winds. The principal areas of upwelling in North America are off the coast of Newfoundland and widely along the southwest coasts of the United States and northern Mexico. On the lee coasts of prevailing winds, water is blown away from the shore and must be replaced by upwelling water, floating up

Fig. 3. Currents of North American seas. The names of the currents are indicated on the map.

from the depths. Conversely, windward coasts accumulate surface water which sinks. This is reflected biologically by the abundant coral forests in the Caribbean where warm water accumulates, and the comparatively depauperate coral fauna of western Mexico where cool water wells up from below. However, these upwelling seas compensate for lack of coral by possessing a great abundance of plant and animal plankton, and very rich oceanic fisheries, largely composed of schooling fishes, become established as a result. In fact, areas of upwelling show the greatest abundance of life to be found anywhere on earth. The champion of all upwelling areas seems to be off the coast of Peru and northern Chile.

There are other causes of upwelling besides winds. These are storms, tides, and the passing of two currents of unequal density (when this occurs, one sinks

and the other rises). But these causes are probably minor in comparison to the effect of winds.

The net result of all these massive water movements is the production of rather stable, but exceedingly complex water masses in the seas, which may be identified by characteristics of temperature and salinity. The complexities of their movement are introduced largely by the lay of the land, that is, conformation of the ocean bottom and of the land masses. For instance, the best known of the horizontally moving water masses, the Gulf Stream, is a distinct, blue river of water, 1,200 times the size of the Mississippi, which pours out of the warm Gulf of Mexico through the Florida Strait at a speed of up to 6 mph. It proceeds north to Cape Hatteras, where it is deflected out to sea, runs into the cold Labrador Current near Nova Scotia, and breaks up into four separate currents before reaching England. Water returns to the Gulf of Mexico by the Caribbean Current to the south. Similarly, the movements of vertical water masses are influenced by the conformation of the bottom. Most of the cold bottom water of the mid-Atlantic is supplied from the antarctic because those of the arctic are blocked by underwater barriers. Local rain, river influx into the sea, melting ice, and sun also have effects on density which greatly complicate the picture.

In summary, the movements of water have, no doubt, a greater effect on the abundance and distribution of marine life than any other physical factor. The oscillating surface factors of waves and tides are mainly responsible for mixing oxygen and carbon dioxide at the surface. In shallow water, they buffet the living and nonliving alike, either building or eroding shore lines and forcing the sessile, or sedentary, animals and plants that live under the impact of their blows to become either massive and thick like corals and sea shells, or flexible and resilient like seaweeds and gorgonians. The nonoscillating water movements are composed of an interplay between two rotating systems, one which is horizontal and caused by winds and one which is vertical and caused by winds and varying water densities. These produce circulating water masses and serve to mix dissolved salts and gases and to distribute animals, particularly planktonic ones, throughout the seas of the world.

ZOOGEOGRAPHY: Communities of Marine Life

It is almost too obvious to point out that the sea is not everywhere the same, but simple statements are often the most important ones. The study of the various environmental differences and similarities that exist in the sea or on the land and the precise recognition of their characteristics allows the recognition of definite *zones*, that is, fairly sharply delimited areas where a certain set of physical features prevail—certain temperature limits, water movements, depths, light, etc. One such type of zone is the tidal, characterized by movements of waves and tides. Another type is the euphotic or lighted zone, discussed in the section on light. Another is the temperate, delimited by certain temperature extremes.

Any zone will have living in it a group of animals and plants that have become specialized to meet the physical and biological requirements of its zone in order to live more efficiently there. All of these forms of life are grouped

together as a *community*. It is usually possible to apply the same names to communities as to zones, and so there are, for example, tidal, temperate, and euphotic communities.

Provinces are divisions of the sea similar to zones but larger in scope. The whole of the deep sea, excepting the very bottom, is spoken of as the oceanic province, for instance.

The communities and zones of land are separated on the basis of plant associations. In the sea, temperature and the nature of the substrate are used. The zones defined by light intensity have already been described. Temperature zonation is simplest and will be considered first.

Temperature Zones

The temperature zones are three in number: tropical, temperate, and arctic. (The temperature zones of North America are given in figure 4.)

Fig. 4. The temperature zones of North America.

THE TROPICS

The temperature of truly tropical waters almost never falls below 68° Fahrenheit. Near shore, most tropical waters are 75° to 80° all year long. Some subtropical waters fall to a minimum of 61° but are not as different from the tropics as are the temperate zones. The tropical seas represent the most ideal

environment for life found on earth so it is not surprising that the greatest diversity of life lives there. The tropics are characterized largely by endemism, that is, a great many groups live there and nowhere else. All phyla of the animal kingdom are represented. High temperature is the basic reason for this, but other factors enter in. For instance, there is an abundant supply of food in the tropics so nourishment is not usually a major problem.

Not only are the tropics characterized by endemism, but animal groups seem to be more diverse there than anywhere else. The most bizarre shapes and habits and the greatest variation in behavior within any group are usually present in tropical members of that group. A review of the fishes adequately reveals this fact.

The tropics are further distinguished by the presence of the lowest tides and the clearest water of all seas. They are the home of the coral reefs and dazzling white coral sands.

Tropical seas are divided into these three regions: the Indo-Pacific, the Atlantic, and the East Pacific, in order of their richness of species and size. Many animals and plants such as the hammerhead shark, all the sea turtles, and many bony fishes are found in all three, that is, they are circumtropical.

Atlantic Tropics. These waters extend north to southern Florida and thence to Bermuda. The whole of the Gulf of Mexico is included. The warm Caribbean and Gulf currents characterize this region. There is good coral growth here, probably richest in the Bahamas, but these are neither generally as lush nor as extensive as those of the Indo-Pacific. The sub-tropics of the Atlantic extend up the eastern coast of Florida to Cape Hatteras. There is very little coral growth here because of low temperatures and the lack of the hard bottom to which coral must anchor (Ekman, 1953).

East Pacific Tropics. Tropical waters reach north to the lower tip of Baja California on the west side of that peninsula, and the whole of the Gulf of California on the east is tropical. The subtropics reach north to San Diego. Upwelling of deep bottom water cools almost the whole of this zone rather drastically at times, and the warm waters are rather shallow in extent. Even in the tropics, water of 54° Fahrenheit lies only 600 feet down. The lower limit of the tropical water is a shallow 300 feet.

This is a distinct zone which bears a few resemblances to the Atlantic tropics, but which, because of the isolation forced on it by the barrier of the Isthmus of Panama and the depauperate central Pacific, has many endemic groups and lacks several tropical groups completely. Ekman (1953) lists the kelp basses, *Paralabrax*, as endemic and says that porgies have only one species, butterfly fishes two species, while parrot fishes, common eels, and manatees are completely lacking.

TEMPERATE SEAS

These are the waters of the greatest temperature variation. Temperatures do not generally rise above 70° Fahrenheit, but they do sometimes reach as much as 80°. However, these zones, being subject to wide seasonal variation, may have temperatures only a little above freezing to the north in winter.

The temperate zones show a wide variety of bottom types from rocky to sandy or muddy. The shores are often covered with dense beds of brown algae, which are scarce in the tropics.

Atlantic Temperate. Atlantic temperate waters lie from Cape Hatteras north to Cape Cod where the Labrador Current ends its southward flow. At Cape Cod the mean annual temperature is 46° Fahrenheit and the extremes are 37° in winter to 66° in summer.

Above Cape Cod is a zone reaching to Labrador that may be called cold temperate, boreal, or subarctic. This is the home of the sculpins, halibuts, rock eels, and of huge schools of cod and herring among others.

East Pacific Temperate. The temperate Pacific lies from San Diego to the Gulf of Alaska. This is a very uniform zone, both in temperature and in flora and fauna, throughout its whole length. Ekman (1953) lists the following August temperatures for this zone: San Diego 64°, San Francisco 55° to 61°, Seattle 61°, and the Gulf of Alaska 57°. The reason for this uniformity is that upwelling cools the southern part and warm currents warm the northern part. The winter temperatures show much greater variation, however, being much colder to the north.

This region has a very large per cent of endemics. Ekman (1953) lists the surf perches, greenlings, and rockfishes (*Sebastodes*), and there are many others. Starfishes are more greatly varied in this region than anywhere else in the world. There are 92 species of them, of which 60 per cent are endemic. The sun star, *Pycnopodia*, is the largest of all starfishes.

The boreal or subarctic Pacific is similar to that of the Atlantic with its cod, halibuts, rock eels and sculpins. It extends from the Aleutian Islands north to the Bering Strait.

Boreal waters in general contain the greatest schools of fishes in the seas. Colder waters have fewer kinds of animals and plants than warmer waters, but this does not prevent those few species from reaching immense numbers in the summer when light is strong, days are long, and surface waters are still cool and viscous enough to support plankton. These constitute ideal conditions for plankton and when they are combined with the upwelling near the Labrador coast, which brings nourishment in the form of dissolved salts to the surface, it is not too hard to see why life is so abundant there. Boreal seas are further characterized by immense beds of algae, rocky shores, and the world's highest tides.

ARCTIC SEAS

Waters of the arctic zone never get warmer than 41° to 45° in summer and reach these heights only for short periods. Ice is an ever-present characteristic whether in floe or iceberg form. These waters are present north of the Bering Strait and Labrador. In general, the boreal animals and plants are also found here, and among them are sculpins, blennies, sea snails, and dense beds of brown algae. Tides are high and shores are rocky in this zone.

Substrate Zones

On land, the word "substrate" usually refers to the ground under our feet, since it forms the support of most terrestrial animals and plants. But in the sea, "substrate" may refer either to the ocean bottom or to the water itself since both are dense enough to support life. (In subsequent chapters, "substrate" is

used in general in the former sense.) Therefore, the substrate of the sea, in which and over which the life of the sea lives, is three-dimensional in contrast to the two-dimensional substrate of the terrestrial world. Flying animals, such as birds, insects, and bats, like fishes, live in a three-dimensional substrate, air.

The ocean is divided into two large provinces, the *neritic*, over the continental shelf, and the *oceanic*, over the deep sea. Both of these are subdivided into two subprovinces, the *benthic*, or sea bottom, and the *pelagic*, or open water. (The divisions of the provinces of the sea are given in figure 1.)

Since "pelagic" simply means "living in the open sea," it usually refers to animals of several types, subdivided according to swimming ability. "Planktonic" (from *planktos*, meaning "wandering") refers to animals whose swimming powers are not great enough to combat water movements. These usually small or microscopic organisms, about 60 per cent of which are diatoms, are the most important life of the sea. The word "nektonic" is applied to animals that move freely through the water. The highest development of free movement is found in fishes and the re-entrants. The use of these terms is rather simple. For instance, the tuna is largely oceanic-pelagic-nektonic. A snail or a scorpion fish is neritic-benthic. Some animals overlap in zones. A bottle-nose porpoise is pelagic-nektonic but is both oceanic and neritic. Some groups are exclusively pelagic, such as diatoms, radiolarians, jellyfishes, arrow worms, pteropods, and some prochordates. In order of abundance among animal pelagic forms, Hesse and others (1951) list copepod crustaceans, pteropods, siphonophores, arrow worms, octopuses, and squids, then fishes. Diatoms are more numerous than any of these.

Exclusively benthic groups include sponges, sea squirts, brachiopods and bryozoans. Most echinoderms, worms, clams and oysters, and snails are also benthic.

THE OCEANIC PROVINCE

The water beyond the continental shelf is divided into zones according to light. For practical purposes, it is best to consider two major zones to be present rather than three previously set up in the section on light. Thus, there is a lighted (euphotic) zone and a dark or abyssal (aphotic) zone. The dysphotic or dimly lit zone is a transitional zone between these two.

The Lighted Oceanic-Pelagic Zone. This zone is, of course, not well-defined from the lightless zone and varies greatly in depth. In general, it is never more than 600 feet deep. All nektonic-pelagic animals, whether they are oceanic or neritic, must be alert or protectively colored or both because of a complete absence of hiding places. In keeping with this, it is here that are found the swiftest swimmers. Coloration is usually countershaded or obliterative (Chapter 2) and is composed of blues or greens above and white or silvers below. The mackerels and tunas are perfect examples of this.

The fishes, squids, and mammals are the dominant nektonic-pelagic animals since their powers of swimming are best. There are no large plants and there is no organic debris (detritus) in this zone, so all of the nektonic species depend upon plankton or plankton-eaters either directly or indirectly for food (Chapter 2).

The nektonic species are slightly heavier than sea water and must swim slowly but constantly to keep from sinking. The swim bladder of the fishes

helps keep them near the surface, but oddly enough some pelagic fishes such as mackerels have no swim bladder. Oil and fat help the mammals rise to the surface, but even they almost never cease moving during the whole of their lives.

Plankton, on the other hand, is largely dependent upon currents. Most planktonic animals and all planktonic plants are microscopic or small, like crustaceans, pelagic tunicates, various larvae, arrow worms, protozoans, pteropods, and diatoms, but some are very large, such as the giant lion's-mane jellyfish, *Cyanea*, the basking shark, and the ocean sunfish (Hesse, and others, 1951). These large planktonic animals are good swimmers, but they usually just drift with the currents. All of the small plankton depend heavily on flotation mechanisms to keep from sinking. The specific gravity of sea water is 1.02 to 1.03 and that of living matter is 1.02 to 1.06. The flotation mechanisms that compensate for this slight overweight are several. Most protozoa, many larvae, and many crustaceans have extensions of their body or skeletons so that they offer great resistance to water. These extensions work best in water of rather high viscosity and are found only on very small animals.

Other animals and plants reduce their specific gravity by various means, such as reducing the weight of their skeletons (pteropods, protozoa, and crustaceans), taking on extra body water (jellyfish), storing oil droplets (fish eggs, basking shark, penguins, whales, ocean sunfish), or by storing gases (Portuguese man-of-war, bony fishes with an air bladder, chambered nautilus).

The Abyssal-Pelagic Zone. The animals of this zone depend entirely upon the rain of dead plankton falling from above or on other members of their community for food. There are no herbivores, and there is usually a direct relationship between the abundance of plankton at the surface and the abundance of life in this zone. Fishes and cephalopods predominate, and these are usually small although exceptions to this rule occur. For instance, the giant squid is the largest of cephalopods. Some protozoa are larger at depths, but this is related to increased viscosity of deep cold waters.

This is a very stable and uniform zone where changes in light and temperature and the movement of water are very slight. Since there is very little water motion, animals with fragile bodies, such as the oarfish (ribbonfish), are common. Many of the fishes are elongate in shape (the chimaera and the frilled shark). Low temperatures in this zone as well as high pressures prevent the efficient formation of lime (calcium carbonate) so skeletons and shells are weak. Pressure also causes protoplasm to take up more water so tissues are gelatinous. Archaic animals are common because of a comparative lack of competition probably.

All over the world, the abyssal zones are rather uniform resulting in the wide distribution of the deep-sea animals.

The Abyssal-Benthic Zone. This is perhaps the least well-known zone of the sea where cold, lightless, almost motionless waters exist. In a few places, a rock bottom is found, but most of the bottom is covered with clay or ooze, the latter being composed of the countless skeletons of planktonic animals and plants. In shallower places, the protozoan oozes cover huge portions of ocean bottom (Chapter 7). This is particularly true of the North Atlantic where the protozoan *Globigerina*, holds forth. A red clay bottom is typical of much of the Pacific and is a very sterile medium for life.

Support and anchorage are big problems in such gooey substrata. Sea spiders (pycnogonids) creep about on long legs. Crinoids and glass sponges have long stalks on which they are supported, and some crabs have hairy feet. Brittle stars are abundant and support themselves on their long arms. The largest known crustacean is the Japanese spider crab with legs that may span 15 feet, lives here.

THE NERITIC PROVINCE

This is the realm of the underwater swimmer. Whereas oceanic diving has been done and will be important in the future, the shallow waters near shore offer greater variety of life and less harsh conditions; almost anyone is able to enjoy these waters. The boundaries of this zone are the shore line and the outer limit of the continental shelf (if it is present) at a depth of about 600 feet. Therefore, the majority of the neritic province is euphotic or well lighted. This province is variable in almost every respect, including nature of bottom, temperature, animals and plants, and water movements.

The Neritic-Pelagic Zone. There is an overlap between the oceanic-pelagic and the neritic-pelagic. Most of what has been said about the oceanic-pelagic also applies to this zone. However, many of the animals of this zone are dependent on the bottom during some time of their life. Pelagic invertebrate larvae usually settle to transform to sessile, benthic adults, and many of these pelagic animals at least feed on or near the bottom. Actually, only a few habitually neritic animals and plants are free of the bottom throughout the whole of their lives, and these are mostly planktonic ones, small species such as diatoms or some crustaceans.

The life of this zone includes planktonic larvae, jellyfish, fish eggs, crustaceans, pteropods, squids, the great majority of sharks and rays, and most bony fishes. Most of these cannot survive if they stray into the oceanic province.

The Neritic-Benthic or Littoral Zone. Of all the zones of the sea, this one shows the greatest diversity of life, especially in a special subdivision of this zone, the coral reef, which will be considered presently.

It is rather difficult to decide how to subdivide this area. From the point of view of water movement, there is said to be an eulittoral or tidal zone, which is bounded by the high- and low-water marks of the highest spring tides and which varies in extent with the geographical location, and a sublittoral or non-tidal zone, which extends from low-water to the edge of the continental shelf. Within each of these are several zones which define the all-important communities of the neritic province.

Some nektonic species such as small fishes are so intimately connected to the benthic region that they may be spoken of as being nekto-benthic. Among these, the reef fishes are notable examples. But mostly, the zones of these benthic regions are characterized by algae or sessile, plantlike animals or other invertebrates.

THE EULITTORAL OR TIDAL SUBZONE

This is the harshest environment of the sea, and the only one that can be thought of as having weather as we know it on land. As the tides cover and

uncover this zone, great changes in wetness, temperature, salinity, light, and friction produced by the harsh buffeting of waves are experienced. On top of all this, food is rather scarce, being present for most animals only when water covers them. This means that the animals and plants of this zone have to be the hardiest in the sea. It also means that from the low-water mark to the high-water mark, conditions become harsher and harsher and more and more like conditions on land, and that life becomes more and more impoverished. Therefore, it is not surprising to find that many eulittoral animals and plants, such as periwinkle snails, blennies, and gobies, show tendencies toward terrestrialism.

This zone is subdivided according to the nature of the bottom into rocky, sandy, and muddy shores. Rocky shores are characteristic of eroding coast lines. This solid substratum forms an anchorage for sessile forms of life such as rockweed (*Fucus*), barnacles, mussels, snails of various sorts. Here life piles on life. As soon as one animal or plant anchors itself to the rock, another may anchor next to it or attach itself to the original resident. Great numbers of small animals live almost exclusively attached to seaweeds or shells. Most of the animals either bore into rock for protection or have heavy shells themselves. The plants are tough and resilient so as to be able to withstand the beating of the waves.

Tidepools are little rock communities in themselves. A great variety of life that can stand wide ranges in salinity, high temperature, and quiet water lives here, including small fishes such as gobies and killifish, bryozoans, hydroids, seaweeds, tunicates, worms, sponges, anemones, barnacles, and mussels.

Sandy and muddy tidal shores are typical of depositing coasts. Marsh grasses such as *Spartina* are invaders from the land and are not bona fide marine plants. The invertebrate fauna is dominated by burrowing forms such as clams, whelks, sand bugs (*Hippa*), and worms. In places where there are no aquatic plants but where marsh grass is found, a great variety of snails, crustaceans, starfishes, crabs, and others are added. Soft bottoms of a mixture of sand and mud are richer than either sand or mud alone. This illustrates the general principle that mixtures of habitats usually produce richer fauna than either habitat does when pure.

THE SUBLITTORAL OR SUBTIDAL SUBZONE

The types of animals and plants of the tidal zone are also usually typical of the nontidal zone, except that the species are richer and more varied here. Once again, there is a division into rocky, sandy, and muddy shores.

The rocky shores bear extremely rich faunas which have at their base great forests of plants or plantlike animals, such as kelp or corals. As in the tidal zone, life builds on life, but fishes are dominant. Animals here usually have heavy protective shells (abalone), spines (sea urchin), or protective coloration (octopus). Every phylum of the animal kingdom is represented, with the notable exception of the exclusively pelagic arrow worms.

The loose substrata of sand and mud are like those of the tidal zone except that they are richer, containing flatfishes, rays, stargazers, anglers, squids, prochordates such as *Amphioxus,* and a greater variety of crustaceans, worms

and molluscs. Furthermore, the sublittoral soft bottoms are frequently covered with lush growths of eelgrass or one of the marine algae which, though rootless, can obtain a foothold in sand or mud. This adds another batch of animals such as sea urchins, starfishes, sea horses, pipefishes, eels, killifishes, and even more worms, molluscs, and crustaceans. The presence of plants markedly increases not only the diversity, but also the abundance of life due to the added oxygen and debris which they bring. Here also, a sand-mud mixture supports the greatest amount of life. As might be expected, coarse sand or gravel supports the least. The forms that live in pure mud are very delicate and usually of fairly deep water, since fine mud particles do not come to rest on the bottom until quiet seas are reached near the outer "mud-line" of the continental shelf.

Special Zones

Three zones, all of them littoral and tropical, must be given special attention because of their unique characteristics. They are (1) a special type of muddy shore, the mangrove zone, (2) a special type of plant community, the Sargasso Sea, and (3) a special type of rocky zone, the coral reef.

THE MANGROVE ZONE

World-wide in muddy, estuarine flats of the tropics grow mangrove trees, especially the red mangrove, *Rhizophora mangle,* whose branching and supporting aerial and stiltlike roots form a swampy tangle in which the fauna of the sea meets that of the land. Crabs, tree oysters, snails, small tropical fishes, snappers, tarpon, and other brackish-water species meet raccoons, land snails, land crabs, and even some fresh-water fishes. Actually the beginning of mangroves usually means the end of the shallow sea for in the roots of the plants, debris and coral, sand or mud are trapped and a land-building process is begun. In fact, as the debris gets thicker and drier, the mangroves themselves die out.

THE SARGASSO SEA

In the great eddy of central Atlantic waters from Bermuda to the south and west toward the Bahamas, *Sargassum,* or sargasso weed, the only floating brown alga, is found in fairly large quantities to form a distinctive community of its own. This weed breaks off from its anchorage on rocks in the Caribbean, especially during hurricanes, and is carried to this sea by ocean currents such as the Gulf Stream. There it lives and grows, but it probably does not reproduce there, until it dies and disintegrates. The total mass of this algae has been greatly overestimated. Clumps of it do become quite large, according to how much gets tangled up together, but it is not a threat to navigation as is sometimes stated. Actually, the area of the Sargasso Sea would be quite sterile of life were it not for this weed, for, though this is the area where the world's clearest waters are found, it is also an area of sinking water where nutrients are rather sparse.

Sargasso weed is brown and leafy (Chapter 5) so most of the animals that live in it are brown and bear leaflike appendages as concealing coloration and form. The weed forms a substrate, a sort of pseudobenthos, for a rather restricted

fauna. A comprehensive list of the fauna given by Hesse, and others (1951), and Ekman (1953) includes a few crustaceans, several hydroids, a few worms, bryozoans, two barnacles, a tunicate, some snails, a sea spider, a pipefish, and the extraordinary sargassum fish. All of these live directly on the weed most or all of their lives. Sargassum also forms a nesting place for flying fishes. The young of many tropical fish use the weed as a place of protection.

THE CORAL REEF

Most of us, if given free choice of places to dive, would pick the coral reef for several reasons. It possesses by far the gaudiest, most varied, and most luxurious fauna of any place where life is found on the earth. In its never-ending nooks and crannies, innumerable animals make their homes, animals which quite frequently have extraordinary habits.

Coral reefs owe their existence to groups of animals and plants which deposit calcium around themselves as a protective skeleton. This building of lime progresses best in tropical waters for two reasons: (1) the chemical reaction which forms calcium carbonate is fastest at temperatures of 68° Fahrenheit and above, and (2) calcium is more soluble, and hence more abundant, in warm waters than in cold.

Though the name "coral reef" is given to a limy reef built largely by stony or madreporite coral, these little colonial animals are not the only reef builders. On almost all reefs the stinging, hydroid millepores, called "fire corals," are very common and, to go farther afield, foraminiferans, calcareous algae such as *Halimeda,* and calcareous bryozoans play a dominant part. In fact, the madreporite corals sometimes even take third place behind foraminiferans and algae in the building of some reefs. Still, the tropical madrepores are the dominant and most spectacular builders of reefs.

Temperature is important; a minimum of 68° Fahrenheit is necessary for the building of coral reefs. The temperature also determines the abundance and variety of corals, for at the marginal temperature of 68°, coral becomes rather depauperate. It takes higher temperatures of about a minimum of 74° to introduce large branching corals to a reef. Borderline waters of 68° such as those off Bermuda, have a noticeably depauperate coral fauna. Hesse, and others (1951), compare Bermuda's 12 coral species to the Red Sea's 125. On the other hand, coral can stand very high temperatures of up to 132° Fahrenheit when uncovered by low tides for short periods. Stony corals do exist in cool temperate waters, incidentally, but reefs are never formed.

Temperature is not the only limiting factor for the growth of coral reefs. Moving water must be present, and it must move at the right speed, not so fast as to break the coral or to prevent the coral larvae from gaining a foothold and not so slow as to prevent the distribution of enough planktonic food and oxygen to keep the coral animals alive.

Coral must have firm substrate to which to attach itself. It is poor or lacking if hard bottom is scarce. Such is the case on the otherwise adequate southeastern coast of Florida.

Coral is usually poor in areas of cold upwelling waters. The eastern Pacific has a poor coral fauna for that reason.

The depth of water influences coral growth. Because of the symbiotic, photosynthetic, oxygen-supplying flagellate protozoans (Chapter 7) that live in coral polyps, growing reefs are not found in waters deeper than about 150 or perhaps 200 feet. Clarity of water has a great deal to do with successful coral growth. In fact, silting can kill coral by cutting down light or by smothering the coral animals.

Lowered salinity will eliminate corals. The mouths of rivers never have coral growths and heavy tropical rains are a reef-destroying factor.

With all these things taken into consideration, it is almost a wonder that reefs are formed at all. Nevertheless, reefs are one of the most common characteristics of all tropical seas, being common between 30° north latitude and 30° south latitude. The Gulf Stream pushes the northern limit up to Bermuda at 32° north latitude. Probably the finest and most extensive coral formations of the North American continent are those of the Bahama Islands.

Coral grows at varying rates depending on the local conditions. A usual average of one inch a year is given by Hesse, and others (1951). The growth of branched coral is sometimes marked by yearly ridges. The American Museum of Natural History in New York has a fine specimen of antler coral from the Bahamas showing these ridges a good two to three inches apart. This is adequately rapid to make nautical charts worth very little after a few years. In places like the Red Sea, whole port towns have had to be abandoned because coral growth made their harbors inaccessible.

The heavy stone corals and brain corals are the foundation stones of reefs. The branched *Acropora* shows great variety of form, being more delicate in deep or quiet waters. All of these look like they are of a permanent nature, rugged and durable, but the story of a reef is not one of mere construction. It is also one of destruction, as is the whole cycle of life. Coral polyps die eventually. Single coral colonies may live and grow over a period of a couple of hundred years, but this process comes to a halt, and if the dead coral is not quickly built upon by new colonizers, its lime will be etched by the waves and turned to sand or redissolved in the sea. Waves are the greatest of the physical factors which destroy reefs. Two more of these are winds and rains. But probably the greatest overall destroyers are boring animals such as worms, sponges, clams, crustaceans and others. Fishes which gnaw on coral, such as the common parrot fishes, also add their bit in destroying coral formations. All of these forces help reduce coral to sand, which sometimes becomes compacted into coral limestone such as that seen on shores near many coral seas. The best reefs to visit are those in which the forces of construction overbalance those of destruction. The practiced eye soon learns to recognize the difference between dying and flourishing reefs, which are sometimes close together.

Three types of reefs are known (*fig.* 5). These are (1) the fringing reefs which closely follow coasts near shore, (2) the barrier reef which is separated from shore by a lagoon, and (3) the coral atoll which is a ringlike island formed by the sinking of a volcanic island at sea. The longest construction ever built by living animals, including man, is Australia's Great Barrier Reef, 1,250 miles of coral formations. The deepest constructions of life are also of coral origin. At Eniwetok Atoll in the Pacific, a boring of 4,000 feet was made through limestone before striking a volcanic rock bottom (Barnett, 1955).

As has been pointed out, the coral reef is the most gaudy and varied realm of life on earth. The animals live so close to each other spatially that they often develop symbiotic dependencies on one another. The pearlfish and the sea cucumber, the conchfish and the conch, and the zooxanthellae and the coral polyps are only a few examples of this.

Coral itself "blooms" at night, the polyps mostly keeping to their limestone chambers by day. In fact, the whole reef teems with nocturnal animals, such as big-eyes, squirrel fish, and others that are more active at night than by day. But even by day the coral reef is a bustling community. So ideal is the protection offered among coral branches and caves that many animals never leave the reefs. This protection also seems to allow them to be more brilliantly colored than elsewhere, but it must be admitted that the reason for the exceptionally gaudy colors of reef animals is not known. Possibly, the colors of the animals have evolved to match the brightness of the light and the clearness of the waters. Competition for space on the reef is keen and is probably another reason for the diversity of life, since the animals attempt to adapt to new situations quickly (Chapter 5).

Most of the life of the reef is benthic or nekto-benthic since almost all of the species, including the large groupers, make their homes in reefs or feed near the bottom. The great majority of benthic groups are represented on reefs as are the great majority of animal phyla. About the only group which is not well represented on reefs is the large algae, chiefly the brown algae (phylum Phaeophyta). Reefs are largely an animal realm and, indeed, very little matter of nonanimal origin is found there.

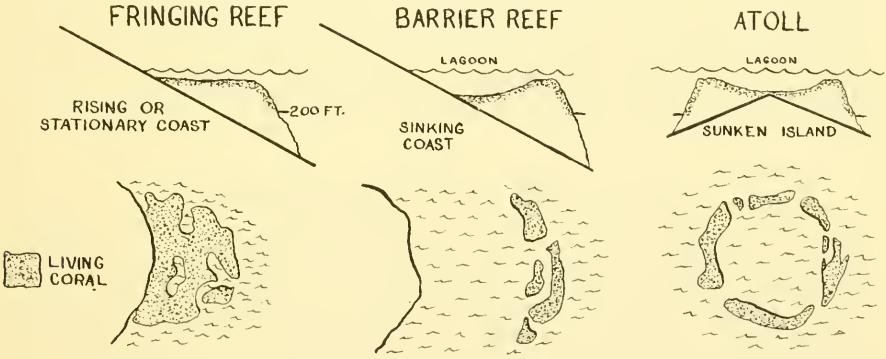


Fig. 5. The three kinds of reefs (adapted from Darwin). The top row of diagrams represents cross-sectional views of reefs; the bottom row, views from above. Each type of reef may be exposed at low tide and may even form the foundation for land formation. Since a reef grows fastest at its outer, seaward border, land masses which are sinking will draw the coral downward. The coral will grow to reach the surface only at its seaward edge and a lagoon will be formed.

CHAPTER 2

BIOLOGY OF THE SEA—How They Live

In this chapter the ways of life of animals of the zones of the sea will be examined under the broad headings of adaptation to habitat, distribution and dispersal, food and food chains, symbiosis, adaptive coloration, animal behavior, and ecology and evolution. Each of these is a huge and complex topic so we can do little more than whet the reader's appetite with general principles here. Furthermore, these few topics by no means exhaust the subject of "how they live." Methods of locomotion, methods of defense, and breeding patterns are three more aspects, for instance (Chapters 7 to 10). It is hoped that the diver will be able to see each animal he encounters under water in the light of the principles that are given so that he will be better able to appreciate the evolution and adaptation of the system of animate nature and also so that he may be able to increase the depth of his experience in the sea. Most of the principles that are discussed, incidentally, are not peculiar to the sea, but apply to all life, including mankind.

ECOLOGY AND EVOLUTION

The nature of the sea and its immutability compared to land—its relative homogeneity and lack of sharp environmental contrasts—has been discussed. In this chapter, we shall see how animals adapt to meet this environment.

Several billion years ago, probably about 4.5 billion, the earth was formed as an immensely hot conglomeration of condensed gases. Over the next few billion years, this mass cooled to the temperature of water in its liquid state; below 212° Fahrenheit. By this time, the earth had become enclosed in a hard, wrinkled crust several miles thick, and this crust had trapped water vapor within it which began to be disgorged from volcanoes in great jets of steam. Huge clouds were formed, and a deluge of rain began to fall, which did not let up until the amount of water equivalent to about one-fifth of all the water in the sea had filled the ocean basins. Cloud formation and rains continued with diminishing intensity until, about a billion years ago, the waters in the seas had reached approximately their present level. It was in the shallow, warm waters of this sea that life arose by a chemical reaction involving combination of chemicals

drawn from the sea's organic "soup." Before the beginnings of the Cambrian Period, about a half a billion years ago, all the major animal phyla had evolved, the history of which still remains largely a matter of mystery. All of these phyla carry remnants of their place of origin in the sea because there is a liquid (plasma) bathing the tissues of all animals which is very much like sea water in its composition. The similarity of sea water and plasma indicates that the seas of a billion years ago, when life arose, were very similar in chemical composition to what they are today.

Only one-fifth of all the total number of species of animals (including insects) are found in the sea, whereas four-fifths live on land. This is in spite of the fact that the sea's area is over twice that of land. It is also in spite of the fact that of the sixty classes of animals, only four are not found in the sea, whereas twenty-five are exclusively marine (Hesse, and others, 1951). Therefore the sea has a greater diversity of groups since most groups originated there, but it has a much smaller number of species than the land. This apparent paradox can be explained by the fact that land, where barriers between habitats are much more difficult to cross, which results in isolation, is a much harsher and more variable environment than the sea. Only the most adaptable animals are able to live on land at all, and these are subject to large and constant environmental changes, with which they must keep step by evolving to meet new conditions quickly. It is isolation, enforced by barriers, and environmental variability that lead to increased numbers of species. Land animals have evolved to a higher psychological order in response to a relatively complex and harsh environment.

Competition is another factor that affects the rate of evolution. Evolution is fastest in areas of most strenuous competition on land or sea. The greatest competition in the sea occurs in the tropical reef areas, where a great number of species are jammed close together in an optimum environment subject to little variation. Consequently the most advanced and highly evolved species of marine animals are generally found about tropical reefs. Toward the deep sea or toward colder waters, environments become harsher, resulting in elimination of species that cannot adapt to these conditions. Thus, fewer species are found in deep and cold waters than in the tropics, and these are subject to lessened competition. This permits some archaic animals to survive in deep or cold waters, whereas they could not survive in tropical, shallow waters. This is the reason that primitive fish, such as isopondyls (herringlike fishes) are mainly found in temperate or arctic zones, in the deep sea, or in fresh waters. The cold and deep waters are harsh enough to reduce the number of species and to reduce competition but, unlike land environments, are not variable enough and have few barriers to impose isolation. The numbers of individuals is great in northern and deep waters, but the number of species is small.

Evolution is not over. Environments constantly change, and all life, including man, must adapt to meet change, or else perish.

ADAPTATION TO HABITAT

Adaptation refers to adjustment between a living animal and the parts of its environment. This is a phenomenon that is exhibited by every living thing

including man and is a direct result of evolution (Chapter 5). Adaptation is exceedingly complex and can never be measured by a single factor such as adaptive coloration, food-getting mechanisms, or breeding habits for the simple reason that adaptation is an adjustment of all the activities of an animal or plant. Because adaptation is so complex, it is never perfect. It is inconceivable that any living thing could perfectly adapt in every way to meet the ever-changing requirements of the environment. This is not to say that adaptation is not very successful, however. The adaptations for speed of movement are not absolutely perfect in the mackerels, tunas, and spearfishes, but these fishes are certainly not inadequate in meeting the demands of their predatory ways.

Adaptation cannot be studied without reference to the question, Adaptation for what? It is not specific enough to say that an animal is adapted for its general environment. We must define what part of its environment, what specific way of life, that animal has evolved to meet. In other words, where in the community does that animal fit in? We know, for instance, that barbers, bakers, and candlestick makers all have their particular adaptive skills in a human community. It is no less obvious that groupers, parrot fishes, and sponges have their separate places in a coral community as well. The adaptive place of every animal is called its *niche,* and in order to define it, the community must be re-examined.

The various zones of the sea have been defined under the section on zoogeography in the last chapter. These zones were shown to be different in their general physical characteristics of temperature, substrate, salinity, etc. In other words, zones are defined by a set of physical characteristics. All the animals of a zone were lumped together in a community, each species of which is subject to similar physical characteristics. Different communities may differ in many ways, but all communities are alike in one respect: Elton (1935) says that the basic ground plan of all communities is dictated by food chains and that the niche any animal occupies is largely determined by its place in the food chain, that is, what it eats and what eats it.

For instance, the herring is a plankton-eater and is eaten by a large number of predatory fishes, such as tunas, swordfishes, etc. Therefore, it is best to define "niche," as Elton points out, by an animal's relation both to its food and to its enemies.

"Niche" is an important concept and the discovery of its niche is vital in understanding any animal. But, of course, the description of a niche cannot tell us all there is to know about an animal. The ways it breeds, moves, is colored, and behaves are all vital aspects that do not derive from a study of food patterns alone.

One point that must be emphasized is that animals are not continually engrossed in one long struggle for existence throughout the whole of their lives. As Elton (1935) emphasizes, animals are not always doing something. It is true that all animals are adapted to a particular mode of life which revolves around feeding, but it is not true that everything animals do or that every anatomical characteristic they possess are of adaptive significance. Some actions or characteristics may have little or no significance. If the diver is to interpret adaptation correctly, he must learn to distinguish between significant and insignificant traits and actions.

Youth, Maturity, Old Age, and Death

"The interaction out of which the organism develops . . . is between the *organism* and environment! And the organism is different at each different stage of its development." (Lehrman, 1953.)

It is rather obvious to us the way environments change through the years or with the seasons. It is also obvious that animals grow, but it is not very widely appreciated what a drastic effect on the life of an animal growth has. Animals start out life as a helpless egg, which soon hatches or develops into only a slightly less helpless hatchling or newborn. This tiny creature goes through a growth period in which increase in size is rather rapid through juvenile and subadult stages. At the onset of sexual maturity, the growth rate levels off, that is, becomes slower and, though growth continues past the onset of maturity, it tends to be slower and slower as time goes on or even to stop. As old age is reached, vigor is decreased, breeding stops, and some animals (man, for instance) even shrink a little in size. Rarely, in nature, do animals die by "natural causes." Predators, parasites, or disease usually spell the end.

There are several fascinating questions that may be raised concerning this cycle of life which every living thing goes through. Some forms of life such as fishes seem never to stop growing. In most animals, aging does not begin until growth ceases and no one seems to know how long fishes could live if it were not for predators, parasites, and disease. Some fishes live one hundred years or more, but it is not known when they begin to grow old. But these questions are not the main interest here. What is of the greatest significance is that this cycle means that as an animal grows and matures, it must pass through a series of stages, each one of which is different from the others. In general, animals are most vulnerable in the beginning of the cycle when they are small, and therefore the process of elimination of the individuals with the greatest negative selective value is strongest in the young before maturity is reached, a fact of evolutionary significance. Those individuals that do survive do so only because they have been able to find food and elude enemies throughout all stages of their life, and in this rather simple statement, we believe, lies the greatest proof of the great delicacy and complexity of adaptation. For instance, the jewfish is a huge, powerful, carnivorous animal when it is mature. But each jewfish starts life as a tiny egg which hatches into a small hatchling. When the young fish starts to feed, it is a fraction of an inch long and must have all the adaptive behavior necessary to allow it to live the life of a tiny, secretive, invertebrate-eating carnivore. Soon it grows to a deep-bodied, little reef fish with many of the habits of other small, spiny-rayed fishes that live alert, watchful lives in rocks and reefs. As it grows, its prey and enemies and ways of life continually change, and, at maturity, breeding behavior adds another facet to its life.

Therefore, every animal may be thought of as passing through a series of very different stages each one of which must be finely adapted to the environment. The greater the animal's difference in size between youth and maturity, the greater and more significant will be its adaptive changes through life. This is the reason why so many fishes have young that are different in so many respects from their parents and are sometimes mistakenly listed as separate species.

DISTRIBUTION AND DISPERSAL

In any community, a number of species is found, each of which has its own distribution (*fig. 6*). Some species might be found in only one community—the parrot fish in the coral reef—and some might be found over a wide range of habitats—the common eel, ranging from the Sargasso Sea to fresh-water streams at different stages of its life.

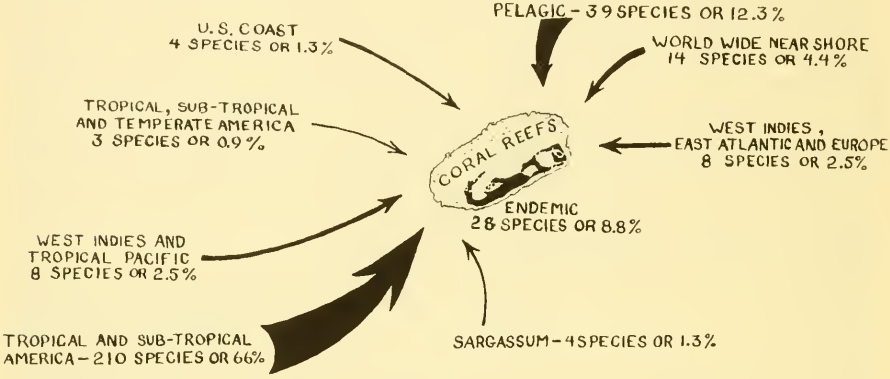


Fig. 6. An example of geographical distribution—species of Bermuda shore fishes (adapted from Beebe and Tee-Van, 1933).

The distributions of the species of a community are far from static, and the numbers of individuals of any one species in a community are subject to constant variation. Some communities are even compound, that is, there may be several animal communities present in any one zone. For instance, the coral reef has strikingly different day and night communities, and the temperate zones have very different seasonal communities. It even sometimes happens that the fluctuation in numbers of one form of life basic to a community may change the whole complexion of the environment. This is what has happened in connection with the decrease in eelgrass in the 1940's.

Fluctuations like these have a great deal to do with factors affecting distribution and dispersal—the questions of why animals are found where they are and how they get there. Such fluctuations complicate the study of communities greatly, because one is never sure just which species are community members and which are not.

The answer to why animals are found in one place and not in another, lies in understanding the principle of *ecological valence*. Briefly, valence describes a range of tolerance which an animal can stand in relation to any factor of the environment. The valence of coral reef formation with respect to temperature ranges from a low of 68° Fahrenheit to well over 100°. The valence of whales in relation to food depends upon the supply of the planktonic crustaceans on which they feed. Both of these valences are small and limiting in value, but valences can be large. For example, the valence of killifishes with relation to salinity ranges all the way from pure fresh water to pure sea water. The valence

of the sperm whale with relation to temperature allows this species to live in all oceans.

Every species of animal has a valence for each of the many factors that determine its distribution. There are valence values for food, temperature, salinity, water clarity, light, pressure, enemies, breeding behavior, shelter, other animals of the community, and all the other myriad factors that affect that animal at any stage of its life. The distribution of any animal is usually not limited by all of these factors but by only one or two. Figure 7 illustrates the *law of the minimum;* an animal's distribution is limited by the factors to which the animal shows the least tolerance.

There are several clues to the discovery of limits to distribution. First, limiting factors are often biotic, that is, have to do with the animals' relation to other animals in the community, and these are sometimes very complex. Second, limiting factors work on all stages of the life of an animal and animals are limited at the stage where they show the greatest sensitivity to environment. For instance, oysters grow in some brackish waters where they are seeded by oyster farmers, but low salinity prevents their breeding there. Third, sometimes the limiting factor is not deadly or even harmful in itself, but affects distribution

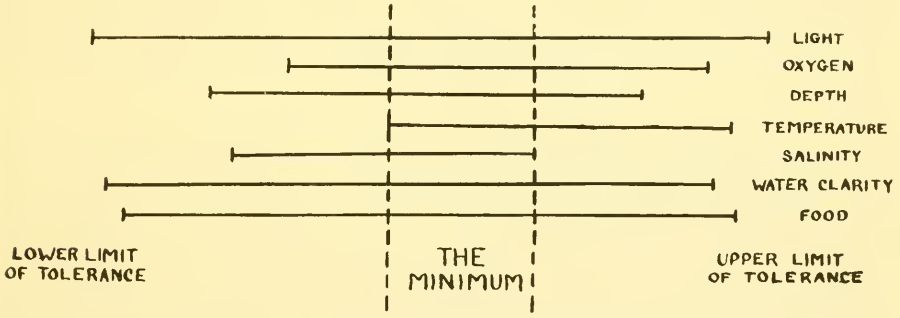


Fig. 7. Ecological valence and the law of the minimum. Each bar represents a valence value for one of the important factors in the life of an animal. Distribution in this hypothetical case is limited by low temperature tolerance and by the high end of salinity tolerance; this animal could not live in waters lower than a certain temperature or of above a certain salinity. An animal's distribution is limited by the factors to which the animal shows the least tolerance.

only indirectly. For instance, light in itself is not harmful to most nocturnal animals, but these animals avoid light for protection against other animals (Elton, 1935). Fourth, limits may often be discovered by noticing a decrease in the numbers of animals near limiting conditions. Animals are most common in optimum conditions or away from limiting conditions. Again, coral is a good example. There are few corals in Bermuda where the lower limiting temperature is reached and many in the Red Sea's optimum habitat. Fifth, rarely does any one species of animal approach its physiological limits. Animals find suitable habitats psychologically and travel the path of least resistance away from marginal conditions, unless they are forced there.

The limits of distribution are complicated greatly by the factors of *vagility*, or the relative power of dispersal of an animal. Sea turtles swim actively and so are found in all tropical seas—they have high vagility. However, many of the groups common to the coral reef communities of the Indo-Pacific are rare or lacking in the east Pacific because their powers of vagility are not great enough to allow them to cross the huge and rather barren central Pacific. Many sessile animals, such as coral and sponges, have pelagic larvae which increase the vagility of the species. Mackerels migrate and have high vagility. Many sedentary fishes or fishes of coral reefs have pelagic eggs or young which serve to spread them to new habitats. In fact, it is relatively common to find young reef fishes far from their parental homes, but rare to find adults of these species far from the tropics. Many Caribbean reef fishes have their distributions listed "north to Cape Cod." This northern extention of range is due mainly to wandering young in the Gulf Stream. Of course, pelagic eggs and wandering young represent wasteful methods of dispersal because many never find suitable habitat and die. For instance, many Caribbean fishes and corals are not found in Bermuda because the wandering young do not live long enough to cross the wide expanse of open sea between these two places. Other methods of dispersal are adventitious (incidentally acquired), for example, sessile animals on ships and driftwood or whale barnacles attached to whales. In summary, the greater the vagility of a species, especially when vagility is by swimming free of the influence of currents (nektonic animals) the more widespread a species is liable to be.

An important factor influencing distribution and dispersal concerns barriers. Barriers are like fences which keep animals from moving out of an area. Barriers are rather obvious on land and consist of rivers, mountains, plains, or deserts that a species can not cross. But barriers in the sea are harder to see and much more variable. Barriers in the sea are also usually of a less severe nature than on land so that most marine animals have wider distributions than are common for terrestrial animals. The most obvious barrier is a land mass. For instance, the isthmus of Panama prevents most Caribbean species from reaching the east Pacific. Land masses separate the major divisions of the sea—the oceans. Other barriers are salinity, temperature, and oceanic currents. How severe a barrier is depends a great deal on the vagility and tolerance of the animal. For instance, powerful swimmers like tuna can skirt around such barriers as land masses, a feat a blenny could not accomplish. Therefore, tunas have wide ranges and blennies small ones.

Barriers seem to the human eye to be of a rather permanent nature, but this is not true. Barriers vary widely in geologic time. The earth's temperature is an example. Not too many million years ago Panama lay beneath the ocean's surface. Because of this impermanence of barriers, distribution is influenced by a third factor besides valence and vagility. This is the *geologic age of a group*. A family of fishes that has existed for 75 million years has obviously had more time to spread itself throughout the seas than a family that has existed for 10 million years. This is why the squirrel fishes, derived from relatively ancient stock, are found in all tropical seas, whereas the grunts of the genus *Haemulon*, relative Johnnies-come-lately, are found only in the New World.

Two more factors concerning distribution must be understood. First, when the range for the green turtle is given as "cosmopolitan in tropical seas," this

does not mean literally that the green turtle is to be found all over the tropics. What it does mean is that this turtle will be found only in the particular habitat of the tropics to which it is adapted, namely shallow beds of marine plants near rocks and coral. Second, the number of individuals of a species to be found in suitable habitats varies greatly with food preference, size, enemies, disease, reproductive capacity, and a number of other factors. Basically, however, density comes down to *carrying capacity,* a measure of the limit of the numbers of individuals the environment can support, which is dependent mainly on food supply.

There are certain psychological checks that prevent carrying capacity from being exceeded. *Territoriality* is the chief of these. This means that a breeding pair of a species sets up and defends a certain area where other members of the species are not tolerated. If breeding space is all taken, individuals that do not find adequate territory do not breed. In species that do not set up territories, carrying capacity is limited chiefly by food.

Carrying capacity is not static. For instance, in summer in north boreal seas, long daylight hours and cool viscous waters support huge amounts of plankton so that the carrying capacity for whales and fishes greatly increases at that time. Therefore, the number of a species found in any area depends upon the carrying capacity for the species in that area at a particular time and is regulated largely by food and the psychological factors.

FOOD AND FOOD CHAINS

Since the adaptive niche of animals is largely defined by their place in the food chain, it is important that this subject be understood if the life of the sea is to be appreciated. Elton (1935) is mainly responsible for focusing attention on this subject.

There would be no food in the sea and no life on earth were it not for chlorophyll and the reaction of photosynthesis. Chlorophyll is present in the great majority of plants and in some plantlike animals such as flagellates, and is a catalyst in utilizing the sun's light energy in the following reaction:

$$\text{Light energy} + \text{carbon dioxide} + \text{water} \xrightarrow{\text{chlorophyll}} \text{sugars and starches} + \text{oxygen}$$

Basically, the food chain involves the following relationship which is common to all communities (with the possible exception of the deep sea, to be discussed later in this section):

$$\text{energy of the sun} \xrightarrow{\text{photosynthesis}} \text{plants} \xrightarrow{\text{eaten by}} \text{plant-eating animals or herbivores} \downarrow \text{eaten by} \rightarrow \text{flesh-eating animals or carnivores}$$

This is an oversimplified diagram, of course. For instance, the omnivores, which eat both plants and flesh, are not included. Neither are the detritus- or debris-eaters which eat dead organic matter from the bottom. Furthermore, there are many grades of carnivores, from the plankton feeders (whales, mackerels) to

the large species which eat large carnivores themselves (killer whale, white shark). Rarely does an animal have a diet that is restricted to only one food species. The dependency of the sperm whale on giant squid, the blue whales on krill, or the sea slug on seaweed are three of the few examples of such dependency. It is much more common to find that an animal will eat a variety of things depending on its food-getting mechanisms and the availability of food species. Probably the animals with the most catholic tastes are the omnivores which eat just about anything they can catch and swallow (some sharks, many crabs, catfishes, etc.).

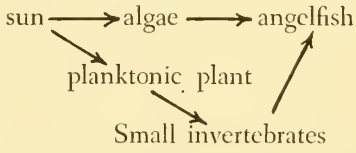
The importance of size on choice of food is easily illustrated. For instance, the killer whale and the blenny are probably equally voracious feeders, but they are forced to eat very dissimilar things because of a vast difference in size. There are exceptions to the size rule that the biggest animals eat the biggest objects. Puffers and killer whales gang up on prey to increase their effective size. Poison, as a food-getting mechanism, increases effective size. On the other hand, the largest of all cartilaginous fishes and mammals (basking sharks, whale sharks, manta rays, and baleen whales) eat tiny planktonic animals.

One primitive mechanism of food getting is filter-feeding and is extremely widespread in the animals of the sea. It always involves the straining of plankton-bearing water. The larger plankton-eaters feed by a filtering process. Such fishes as whale sharks, mackerels, and herrings, filter with gill rakers, and whales filter with baleen. Many groups of invertebrates also filter-feed. Among these are clams, oysters, sea squirts, sponges, crustaceans, corals, many worms, and salpas. Some of these, such as crustaceans and salpas, are planktonic and form a vital link between small, single-celled planktonic plants or protozoans and the large fish or mammal plankton-feeders. The other groups are sedentary and depend on small plankton brought to them by water currents.

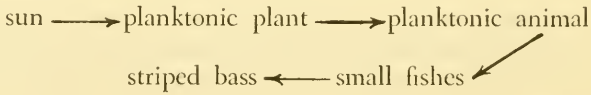
A food chain may be drawn for any animal in the sea. Examples of food chains follow. (The arrow points from the food or energy source to recipient.)

Oceanic, plankton-eating, carnivore food chain (whale):

Coral reef, omnivore food chain (angelfish):



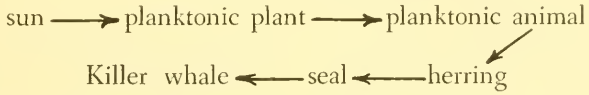
Inshore, carnivore food chain (striped bass):



Each of these examples is somewhat simplified. The striped bass, for instance, does not eat only small fishes, but may also eat crabs, but in spite of this, food chains are short. The shortest consists of three steps and concerns herbivores as follows:

sun → algae or turtlegrass → green turtle

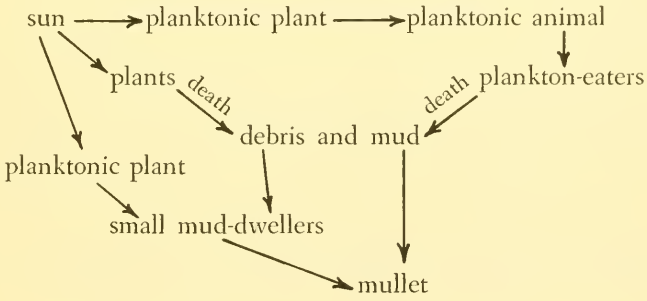
The longest are of the large, voracious carnivores, but these are lengthened only because of a step-by-step increase in the size of the carnivores involved:



It is often stated that parasitism and mud-eating are examples of simplified food chains. This is not really so. For instance, the mullet is a mud-eater, but its food chain is not the following:

mud → mullet

Instead this food chain is quite complex as follows:



Therefore, the mullet's diet of mud consists of three separate food chains, all of at least four steps. Similarly, the parasite's food chain is not simple but is exactly like that of a carnivore in that it involves flesh-eating.

One food chain deserves to be somewhat set apart from the rest. This is the food chain of the deep sea. It is a popular opinion that life decreases from the surface to the bottom, but several scientists, including Beebe, Barton, and Jacques Cousteau (Cousteau, 1954), have remarked that life decreases to the dimly lit or dysphotic zone and then increases downward. Deep plankton forms the DSL (deep scattering layer) which can be detected on echo-sounding devices. Direct observations made from the bathyscaphe, a remarkable undersea boat which uses the principles of an aerial balloon, indicated an increased abundance of life with depth and that the DSL is the top layer of this abundance. This has led Cousteau and others to suspect that some unknown link in the food chain is responsible.

While it may be true that little is known of the deep sea, we do not believe that an unknown link in the food chain is necessary to explain the abundance of life in the depths. The sun is still the source of energy, although indirectly, but two food chains, which are linked together, are really involved, one at the surface and one in the depths (*fig. 8*). Life in the depths is connected to the fundamental reaction of photosynthesis at the surface and is not self-sustaining, but the basic form of life in the depths is not photosynthetic; it is bacteria which cause decay and nitrification. Bacteria is a sort of "plankton of the depths" with respect to food chains there, and since bacteria is most abundant at the bottom, so are the animals that feed on bacteria.

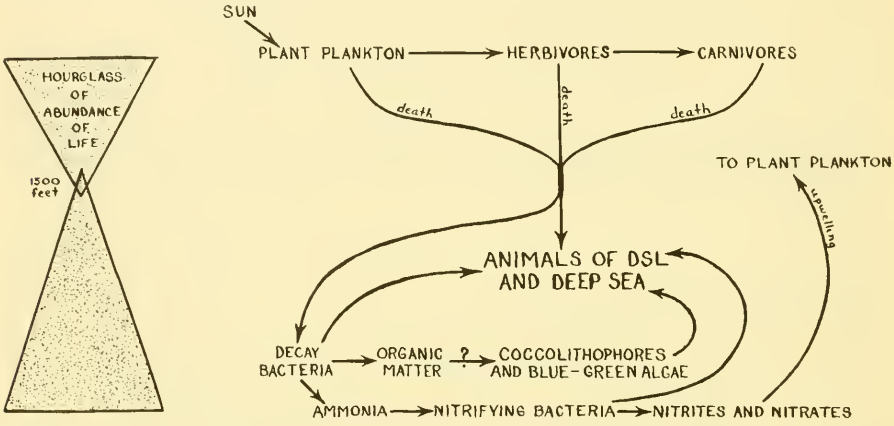


Fig. 8. Deep sea food chains. Animals of the deep scattering layer (DSL) and deep sea are dependent upon two sources for their basic food: 1) the constant rain of dead animals from the surface and 2) the deep water plankton consisting of various bacteria and simple plants. Both of these sources are dependent upon the sun, directly or indirectly, for energy. Since surface life is most abundant in the first 250 feet of water and bottom life is most abundant in the deep sea, a graphic representation of the numbers of animals at various depths takes the form of an hourglass as shown on the left.

So far, we have dealt only with food chains involving a few animals. When a whole community is considered, the food chains of all the species must be added up to form a food cycle. Figure 9 shows a greatly simplified cycle of the coral reef.

Food chains have a great effect on animal numbers. Carnivores, for instance, could never become more numerous than the herbivores they eat. It is estimated that for every planktonic animal there are seven planktonic plants. The numbers of planktonic animals per baleen whale is almost inconceivable. Figure 10 shows a *pyramid of numbers* in which the most numerous forms of life are shown to be the photosynthetic plankton and the least numerous are the large carnivores. This concept explains the relative rarity of the extremely large, voracious predators like the killer whale and the white shark.

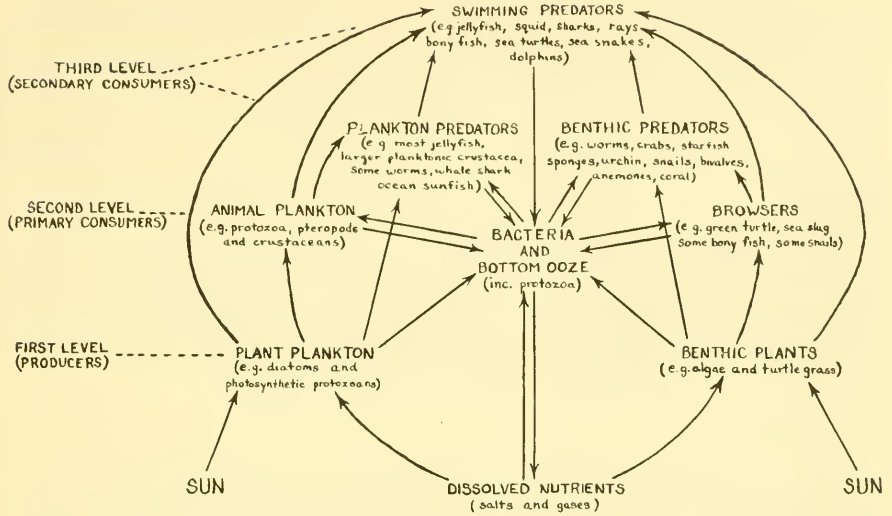


Fig. 9. A simplified food cycle of the coral reef arranged in order of energy (food) source levels. This is a representation of the total of all the food chains in the community using animals from the coral reef as examples. The first level is photosynthetic, the second level herbivorous, and the third level carnivorous. However, any one animal may belong to more than one level—the omnivore which eats both animal and plant matter. Bacteria may be said to constitute a fourth level since they live on decaying matter. In general, the higher the level the less is the dependence upon the level immediately preceding for food and the more efficient the use of the food supply. Conversely, the higher the level the greater the energy loss through respiration, a fact related to the increased activity in the animals of the higher over those of the lower levels. (Adapted from Allee and others, 1950.)

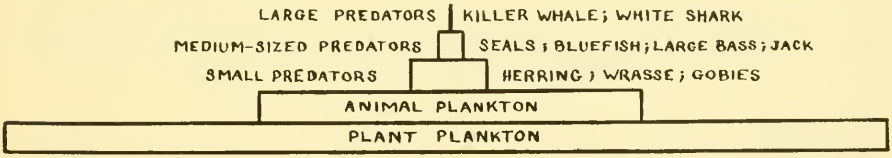


Fig. 10. The pyramid of numbers; the higher the energy level (fig. 9) or the farther out on the food chain an animal is, the less numerous it is. The rectangular areas represent relative numbers of animals. Examples are given opposite each rectangle.

SYMBIOSIS

The word "symbiosis" is derived from *syn,* meaning "together" and *bios,* meaning "life" and means nothing more or less than "living together." An animal that lives with another is called a "symbiont." There are various ways, however, in which animals and plants do this, ranging from nothing more than

an occasional meeting in a community to the exceedingly delicate adjustment required by parasitism or mutualism.

From the purely chance meetings of species to the most delicately adjusted symbiotic relationship, all shades of gray exist. Therefore, in order to identify the three main categories of symbiosis—commensalism, mutualism, and parasitism —the diver will often find himself in the position of having to make value judgments as to just what the advantages or disadvantages of a relationship might be.

The evolution of symbiosis is bound to progress from the disjunctive (no constant bodily contact) to the conjunctive (constant bodily contact), but from there the paths of evolution diverge. Perhaps the most ideal relationship is one in which both symbionts are benefited (mutualism). Commensalism evolves into parasitism, and parasitism often evolves into mutualism.

Commensalism

This is a relationship in which the symbionts share the benefits unequally, one receiving advantage and the other not affected except, perhaps, in a minor way. Therefore, the symbiont receiving advantage is active and the other is passive. The active member may benefit by obtaining shelter, support, locomotion, or food (exclusive of the tissues of the passive member).

Commensalism is the least involved of the three special types of symbiosis discussed here. It is most often disjunctive, but approaches being conjunctive in some cases and is either social or nutritive. If nutritive, however, the relationship is not antagonistic.

Well-known examples are the pearlfish, which uses the cloaca of the sea cucumber for retreat, the conchfish, which uses the conch for the same reason, and the many bony fishes which live in seaweed or under the bells of jellyfishes. In the case of the man-of-war fish, commensalism is very near to being conjunctive since this fish is rarely seen out of the company of the Portuguese man-of-war and even feeds on some of the food that the jellyfish captures. A truly obligatory conjunctive commensalism is found in the whale barnacles which can only live on whales, the benefit of the association being all theirs.

Mutualism

In this symbiosis, both symbionts share the benefits of the relationship. Both species need not benefit in the same way; in fact, they usually do not. One may receive shelter or transport and the other food. The fine adjustments necessary for two animals to live and benefit together are sometimes very extraordinary.

Usually mutualism is conjunctive, though it may be disjunctive. It is either social or nutritive and is always non-antagonistic. As in commensalism, examples from the sea are common and striking. The zooxanthellae of corals is one. Crabs show mutualistic relations with anemones in which the crab carries the anemone about on its back; the crab is protected by the stinging tentacles of the anemone, and the anemone receives transport and support. Some crabs even hold anemones in their claws and use these as weapons or food-getting devices. Other hermit

crabs become clothed in a sponge, which gives the crab a home and the sponge transport. These are conjunctive examples. Disjunctive examples are found among butterfly fishes, which relieve large predators such as snappers of throat and body parasites with satisfaction to both parties.

Parasitism

In parasitism, which will not concern us very much in this book because most parasites live within the bodies of other animals and cannot be seen, the relationship is either conjunctive or disjunctive and is always antagonistically nutritive. One of the symbionts is small and benefits by partaking of the tissues of a larger host. The host is always harmed to a greater or lesser degree. Parasitism is derived from a predator-prey relationship, in which the parasite has become adapted to feed on only one host (see lampreys, Chapter 8). In any case, the ideal parasitic relationship is not one in which the parasite kills its host, for in so doing it destroys its own home and its source of food.

Parasites include various groups of worms, crustaceans, and protozoans among others. Many of the phyla of the animal kingdom have parasitic members.

Certain worms and the remarkable deep-sea angler fish, *Photocorynus*, have males which are parasitic on the females. The male angler, for instance, attaches himself at an early stage of growth to the body of the female. He is a true parasite, receiving all food from the female, and degenerating to a small animal containing reproductive organs only.

ADAPTIVE COLORATION

Whether the colors of an animal are changeable or not, the colors it exhibits at any one time are very often adaptive in nature, that is, are of some benefit to the animal in its environment. Color adaptation can take several forms—concealment or warning, for instance—but in every case it is important to view the colors of animals with careful reference to the animal's environment, its behavior there, and the characteristics of the visual receptors of other members of its community. Otherwise, colors lose their meaning. Furthermore, it is necessary to realize that not all colors and color patterns are adaptive. Some colors have no adaptive significance. Thus, the tasks that are faced when studying colors are, first, to determine if the coloration is adaptive at all and, second, to determine what purpose the adaption serves. Sometimes the adaptions are obscure, and the diver must be very careful in his interpretation.

Animals change color with response either to environment or to stimuli associated with courtship or fear. The colors of fighting sailfish become noticeably more intense; the octopus shows a nearly white color phase when it is frightened or alarmed; blennies and gobies change color with sexual excitement during breeding.

Adaptive coloration has been reviewed by Cott (1940) in a brilliant book on the subject. Cott begins his book by pointing out the very important fact that vision rests upon a three-fold basis. First, the physics of light is responsible for the intensity and quality of rays that emit from an object. Second, the physiology of the eye and nervous system gives a picture of that object to the

brain. Third, and most significant, the brain interprets that picture. The eye picks up a picture, but the brain does the interpretive "seeing," and, in general, the brain sees only what it knows. This means that past experience has a great deal to do with what is seen. The whole point of adaptive coloration is a play on the interpretive part of vision.

Concealment—*Cryptic Coloration*

In the case of concealment, adaptive coloration serves the purpose of making the adaptively colored animal harder for its enemies to detect or harder for its prey to notice. In other words, the clues by which detection of an object is made are rendered inconspicuous. Methods of concealment are four in number:

1. Color Resemblance. The most common method of concealment involves colors and color patterns that match the background. The flatfishes (*color photograph*), round sting rays (*fig. 76*) and the cowfish (*fig. 12*) show this admirably in their resemblance to substrate. The octopus is another notable example of an animal that matches its surroundings. The red colors of moderately deep-water or nocturnal animals might be adaptive, making these species appear black. Several deep-sea animals and the larvae of eels, tarpon, bonefish and ladyfish are almost completely transparent, which is a protective lack of coloration that imitates the transparency of ocean water.

   Some animals change colors throughout life to match their changing environments. Cott gives the examples of the flying fishes, which are brown when young in sargasso weed and blue when adult in the open sea, and the sea slug, *Aplysia* (*color photograph*), which changes from red when it lives on red algae when young to olive-brown when it lives on brown algae as an adult. Great numbers of bony fishes and a few sharks are able to change color, being, in general, of lighter coloration in open water over a light bottom or near the water's surface and of darker coloration over a dark bottom or near dark places.
2. Obliterative Coloration. This adaption is encountered mostly in open-water species and is explained by figure 11. It involves countershading, in which the animal is darker above than below. This, in combination with illumination from above, makes the animal look flat and inconspicuous. Mackerels are excellent examples of this. The diver who has seen the barracuda swim toward him like a ghost has seen another good example of obliterative coloration. Countershaded fishes appear dark when seen from above, and when seen from below appear light against the surface. Most fishes are countershaded in addition to their other coloration adaptations.
3. Disruptive Coloration. In most cases, matching colors alone are not enough to conceal an animal. Methods which break form and outline, the greatest of all clues to identification, are very often employed. Stripes or bars are effective in breaking outline as shown by figure 12.

   The jaw outline of many bottom-living predators is concealed by the presence of fleshy, protectively colored tabs. Such is the case with toadfish, anglers, stargazers, sculpins, and scorpion fishes.

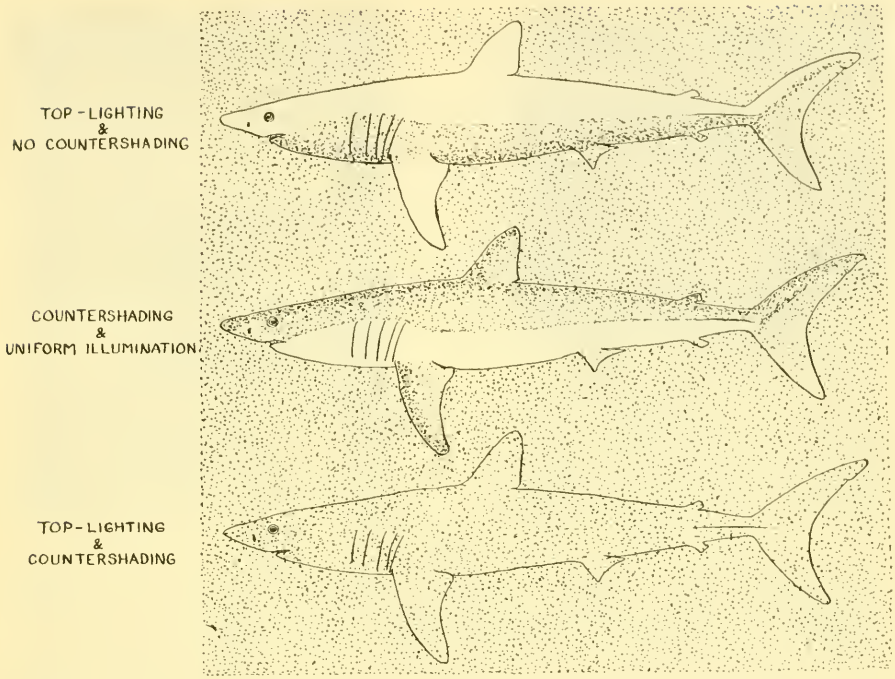


Fig. 11. An example of obliterative coloration—the mako shark. The top figure shows the shark as it would appear if it were uniformly colored and lighted from above—a shadow is thrown on the lower side and the animal is conspicuous. The center figure shows the shark uniformly illuminated, but colored darker on its back (as the mako shark actually is)—still conspicuous. The bottom figure shows the shark as it actually appears in the water with a combination of top-lighting and countershading—flat and inconspicuous. (Adapted from Cott, 1940.)

The eye of many animals, being an especially noticeable part of the body, is frequently concealed by a stripe or disguised as those of butterfly fishes (*color photograph*) and the porkfish (*Color Plate* 5). The eye also may be included in the pattern of the rest of the body, as seen in anglers, some groupers, and the scorpion fish, by extending body pattern and color onto the eyeball.

4. Shadow Elimination. Animals are very often not betrayed by their own bodies but by the shadows that they cast. Shadows frame animals conspicuously, and the elimination of shadows is a valuable aid in avoiding detection. This method of concealment is common in bottom fishes. Depressed species such as rays, flatfishes, and batfishes cast little or no shadow.

Rarely is only one of these four methods of concealment used by an animal. The mackerel shows obliterative coloration, but its blue to blue-green ground

Fig. 12. Four examples of disruptive coloration in tropical reef fishes. Upper left: the ribbonfish, Eques *species, is vertically striped on its head and horizontally striped on its body, which serves to break the fish into two major parts. Upper right: a midget bass, the harlequin serranid,* Prionodes tigrinus, *breaks its body into segments with vertical bars and puts a stripe through the eye to mask it. Lower left: the Nassau grouper,* Epinephelus striatus, *breaks the outline of its massive jaws by continuing the pattern of stripes from the snout onto the lower jaw (note the conspicuous tuning fork pattern on the forehead, a good identifying characteristic). Lower right: the cowfish,* Lactophrys tricornis, *shows a disruptive coloration as well as color resemblance and protective habits, all of which cause the fish to look like a rock (a large stone coral is at the right in this picture).*

color matches the open water, showing color resemblance as well. The sergeant major has bars for disruptive coloration, color phases which match environment, and countershading. The octopus is one of the few animals that shows only one method, color resemblance, though even in this case, its sometimes noticeable blotchings could perhaps be interpreted as disruptive coloration. The round ray is both protectively colored and flat to eliminate shadow. These examples should serve to illustrate the point. Do not look for one simple answer to concealment; it is most often a combination of interplaying factors. Concealment of one part of the body may even be combined with advertisement of another part. For example, the four-eyed butterfly fish conceals its real eye and advertises a posterior false eye.

Advertisement—*Aposematic Coloration*

Diametrically opposed to concealment is advertisement. Some animals are conspicuously colored either to serve as a warning or as an aid for food-getting. Bright colors and striking patterns by themselves do not reveal to us whether an animal will be conspicuous or not. Rather, how the animal looks to the other members of its community is again the important criterion. Animals that advertise are frequently sluggish and stand their ground, especially when they are protected by having poisonous spines or flesh. They are sometimes gregarious, so that their conspicuousness is reinforced by their numbers, and they usually display themselves freely.

There are two aspects to advertisement, action and color pattern. Sometimes these work alone, but they usually go hand in hand. Animals that are conspicuous-looking in their environment also act in a conspicuous way.

1. Warning Colors. Conspicuous colors are sometimes taken on by animals to advertise the fact of their ill-tasting flesh, poisonous flesh, poison spines, or anything else about them that is definitely distasteful or dangerous. These animals travel more or less with impunity and with little fear of attack. This, of course, involves learning on the part of the predators which avoid attacking these animals. By advertising themselves, recognition is made easier, and there is reinforcement of dangerous qualities by striking appearance. Many sea slugs (nudibranchs) are very brightly colored to advertise their distastefulness (*Color Plate 10*).

   Warning display goes hand in hand with warning colors. The porcupine fish inflates not only in order to appear larger, but also as a warning of its dangerous spines and poisonous flesh. The sculpins erect their preopercular spines when molested. The squids and octopuses cause waves of color to pass over their bodies, causing hesitation on the part of predators. Toadfishes utter a grunt probably as a warning to advertise the power of their jaws.

   Some warning colors are adventitious and the result of symbiosis. Thus, the man-of-war fish achieves protection due to the warning colors or form of the Portuguese man-of-war's tentacles. Some Indo-Pacific demoiselles live in the protection of stinging anemones. One crab uses a live anemone, held in its claws, as a warning to predators.

2. Conspicuous Localized Characters. In some cases, it is not the whole animal that is advertised but some specific part of it. Lumped in this category are a wide variety of fascinating examples, most of which involve some sort of misrepresentation or deception and which can almost be thought of as being a sort of concealment-advertisement combination, for in making one part of a body conspicuous, the other parts are made much less so.

The one sort of exception to this general rule is exhibited by animals which conspicuously advertise a particularly dangerous part of their bodies. No deception is involved here. The sharp, preopercular spine of angelfishes is usually a bright yellow. The poisonous spiny dorsal fin of the European weaver, *Trachinus,* is a conspicuous black. The lancetlike white spine on the caudal peduncle of the blue tang contrasts with its otherwise blue body. Electric rays frequently have ocellar spots on their backs as warning marks.

The other purposes of conspicuous localized characters are several and involve misrepresentation as stated above. First, conspicuous contrasting colors may serve to startle predators. This is a protective device involving bluff. The batfishes spread their pectoral fins to show a startling black and white banded pattern when threatened. Sailfishes are known to erect their huge dorsal fins when fighting or excited, and they may thus alarm aggressors.

Second, conspicuous colors may serve to lure prey to the most dangerous part of an animal. The angler fishes use their first dorsal spine as a lure to attract prey, and the stargazers have a similar lure inside their mouths. In both of these cases, the lures are wiggled to make them even more conspicuous. Anemones have attractively colored stinging tentacles which lure small fishes to their deaths.

Third, conspicuous characters may serve to distract attention away from the most dangerous part of an animal. The cuttlefish, *Sepia,* and probably other squids as well, exhibits rapid waves of color on the posterior part of its body, which draw attention away from the tentacles. When the cuttlefish draws close to its prey, these relatively inconspicuous tentacles are shot out, and the capture is made.

Fourth, colors and conspicuous marks are often used to misrepresent the posture or position of an animal or to direct attack to less vulnerable parts of the body. The combination of an eye stripe and an eyelike spot near the tail of the four-eyed butterfly fish creates the impression that this fish is swimming backwards. Longitudinal stripes through the bodies of such fishes as shark-suckers, cobia, and the rainbow runner make these animals appear to stand still while they are actually moving speedily forward. Squids, octopuses, and some sea slugs (*Aplysia*) emit clouds of inky fluid when annoyed, which confuse an enemy and mask their retreat. Some animals leave parts of their own bodies behind to confuse enemies. This habit is called "autotomy" and is well known in the cases of many lizards, including the glass "snake," which can discard its tail at a moment's notice, then grow a new one later. In the sea, the crustaceans are the best-known practitioners of autotomy. Many of them have a special autotomous joint where a limb may be broken off. This limb then wiggles

furiously for a minute or two, distracting the enemy, and allowing the crustacean a chance to slip away unnoticed. The discarded limb may be eaten, but this doesn't bother the crustacean which simply grows another as good as the one lost.

Disguise

Disguise is like concealment, but in the case of disguise the resemblance to objects is real and not abstract. That is, animals are adapted not just to become inconspicuous by destroying parts of their own identity, but by resembling objects about them. Cott (1940) calls these animals "posers." Concealingly colored animals are "self-effacers." Disguise is put on either for protection or ambush as is the case with concealment.

The sargasso weed community shows several good examples of disguise. The sargassum fish (*Color Plate 10*) and some crustaceans that live in this weed are not only colored like the weed, but they bear fleshy, weed-resembling protruberances on their bodies.

Several sea horses and pipefishes bear extensions of their bodies to make them look weedy. The angler, *Lophius*, is colored and roughened to look like a flat rock. Scorpion fishes look like weedy pieces of coral rock. Filefishes imitate floating seaweed. The decorator crab, *Stenorhynchus*, clothes itself with seaweed as an adventitious disguise. Several other crabs become clothed with sponges or anemones in a symbiotic relationship.

Disguise is particularly interesting because it demands not only that an animal look like some foreign object, but also that it act like that object. The trumpet fish is brown and slender like a gorgonian stalk, but this effect would be lost if this fish remained horizontal. Therefore, trumpet fishes assume a vertical position (usually near gorgonians) when alarmed and let the water currents sway them so that the illusion is complete. Similarly, the angler fish stays motionless like a rock and the sargassum fish moves very little in sargasso weed in order to accentuate their disguises.

Mimicry

Mimicry involves a resemblance even stronger than in disguise for it involves strong imitation of one living organism by another in both habits and appearance. The purpose of mimicry is restricted to warning and false warning.

Two types of mimicry are known. First, if a relatively scarce, palatable, or nondangerous species mimics a relatively abundant, distasteful, or dangerous species, Batesian mimicry is said to exist. This mimicry involves learning by predators of the pattern of color and form of the distasteful species which is not eaten. Animals which imitate this distasteful species then are presumably also not eaten. However, the mimic can never become abundant or the learning of the warning pattern is weakened. For instance, the tasty viceroy butterfly mimics the distasteful monarch, but viceroy butterflies are much less plentiful than monarchs and are generally shunned by predators. Examples of Batesian couples in the sea are rare. Cott states that the English sole, *Solea vulgaris*, has a dark spot on its side which mimics the black, poisonous dorsal spines of the European weaver fish, *Trachinus*.

Second, if a number of species, all of which possess the same distasteful or dangerous attributes, come to resemble each other, the association of dangerous qualities with their appearance is made simpler for the predator, that is, learning is reinforced. Perhaps this is why the distasteful sea slugs (nudibranchs) look so much alike and are so brightly colored.

ANIMAL BEHAVIOR

The purpose of this section is to give some understanding of the principles involved in activities of marine animals as they adjust to their environments. The stories of fish behavior told by fishermen and others who come in contact with the sea are often interesting and fascinating, but for the most part they have been greatly misinterpreted. Often human qualities have been attributed to fishes and superficial conclusions drawn from only bits of behavior. To the diver who has to deal with the aggressive fishes in their environment this can be dangerous. A more rewarding approach can be taken by careful scrutiny of the evidence available. This involves looking into the physical and mental equipment possessed by marine animals, into the kind of behavior one can expect with a particular type of nervous system possessed by an animal, and into the part that sense receptors (visual, olfactory, etc.) play in their total behavioral adjustment to their environment.

It may become apparent to the underwater naturalist as he studies the marine animals and their environment that these animals do not perceive their environment as the diver does. Many of these animals are deaf (the starfish, worms and snails, and probably some fishes). Many are blind, others have poor vision (sharks and rays), and some have excellent vision (some bony fishes, squids, octopuses). It is suspected that some fishes can hear sounds of higher frequencies than humans. Most fishes, such as the bottom feeders, have a highly developed sense of smell and are able to detect very weak chemical concentration. It becomes clear that the underwater world as seen by the diver appears different to each species, and what sometimes appears to be bizarre coloration, shape, or behavior in a fish to the diver can be explained as a method of survival adapted to the sensory and motor abilities of the animal that feeds on it. The diver perceives the underwater world mainly through vision. Man's vision underwater is far superior to that of fishes. He is very sensitive to color, he can focus over a wide range of distances with excellent visual acuity, and he is a good judge of distance because of binocular vision. But he is limited when compared to most fishes, for their behavior depends upon smell and lateral line receptors for contact with the environment. Man cannot smell underwater nor can he detect vibration as fishes can over great distances. This makes man primarily a *day* animal in the sea, for at night, unless he brings a light source with him, he loses his visual superiority and becomes as helpless as a fish out of water.

Marine Invertebrates

The behavior of marine invertebrates is for the most part dependent upon the type of structural equipment (action equipment, sensory receptors, nervous

system) that a given species has and upon the environment in which it is able to live. It is able to live in a particular environment only if the environment continues to provide the stimulus (light, food, temperature, etc.) to which its receptors are capable of responding. The higher vertebrate animals (mammals) have advanced structural equipment (well-developed nervous system, sensory receptors, and action equipment) which, in contrast to invertebrates, is well integrated, making possible complex behavior patterns and modifications of behavior by learning from previous experience.

Behavior of invertebrates varies, depending upon the efficiency of their sense organs, the type of nervous system, the kind of action equipment possessed, and it is also dependent upon the animal's past experience and inherited instincts. The intelligence of a species is determined by the degree to which sensory receptors cooperate with one another in governing the nature of behavior.

The marine sponge, *Sycon* (phylum Porifera), is one of the lowest of invertebrates. After its free-swimming larva stage, it attaches itself to the bottom and becomes immobile, filtering its food from the surrounding water. There is no nervous system. There is only protoplasmic transmission of impulses from one cell to a neighboring cell, each cell serving the combined functions of action equipment and receptor. Pore cells are stimulated by water currents and chemicals, which start the beating of flagellated cells found lining the body walls. This animal has no other sensory receptor and its stationary existence makes it completely dependent on its environment.

The sea anemone (phylum Coelenterata), more highly organized, shows an advance in sensitivity to its environment far greater than that of the sponge. It is able to move if the food supply becomes scarce, and it grasps its food by its tentacles and passes it to the mouth. These tentacles have contact sense and chemical sensitivity. The anemone also shows a reaction to light. The actions of coelenterates are integrated by the most primitive type of nervous system known, the nerve net (*fig. 13*).

The brittle starfish is part of a group called "echinoderms," which include the starfishes and sea urchins (phylum Echinodermata). They are slightly higher in psychological position than the sea anemone because of their more efficient type of nervous system involving a nerve ring (*fig. 13*). The nerve ring is not a controlling center like a true brain but is a more efficient transmitter of impulses than the nerve net. This nerve ring is used mostly for controlling locomotion, and cooperation between parts is slightly better than in the coelenterates. These advances, although the echinoderms have radial symmetry, usually allow whatever area is more strongly stimulated to take the lead in locomotion. Brittle stars are sensitive to light, moving about at night capturing their food. The light-sensitive cells are found at the ends of the arms. The sea urchin has light-sensitive pigmented spots on the body. Chemical-sensitive buds are found on the tentacles, tube feet, and the mouth area of brittle stars. The whole body is somewhat chemically sensitive with the ventral side slightly more so. Contact sensitivity is well developed and is important for locomotion. Contact receptor cells have hairlike projections found on the tube feet and tentacles. The sea urchin relies on the spines for its contact responses. Most starfish move about with the action of the tube feet. The brittle star moves by the action of its arms, which are powered by large muscles. The sea urchin, when excited, moves by the spines. Otherwise it uses its tube feet.

The worms (phylum Annelida) have a definite advantage over the starfishes and sea urchins in that the head end of the body is well supplied with sense organs, there being progressively less sensitivity toward the posterior end. This permits the head to take the lead in behavior and makes possible a more complex

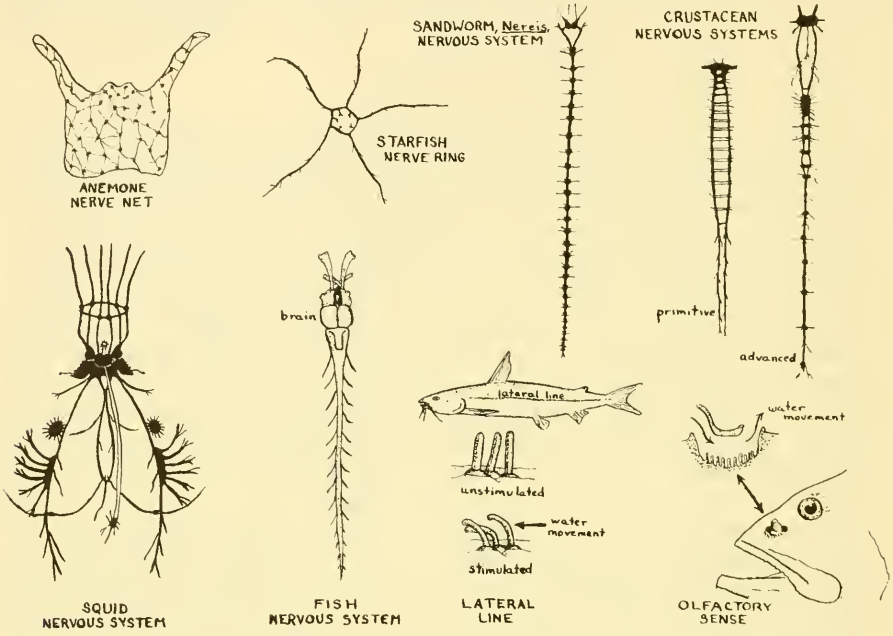


Fig. 13. Nervous systems and sense organs.

adjustment to environment. The sandworm, *Nereis,* is an example of this group. It burrows into sand and has its chemoreceptors (smell, taste) mainly on the head end of the body, allowing a more directed food-locating behavior than is present in echinoderms. One other factor important in this group for adaptive orientation is the development of a centralized nervous system involving a brain (*fig. 13*). These improvements of nervous structure with concentration on the head end integrate the body processes in a better way than the lower animals previously discussed. The marine worms have paired ocelli (simple eyes) which are sensitive to light, and the worms react by hiding by day. Chemical sensitivity is mainly located on the tentacles on the head end although there is some sensitivity on the tail and body appendages. There is strong sensitivity to vibration from the substrate.

Some members of the phylum Mollusca (snails, octopuses, and squids, but not clams and oysters) have a much better-developed head end, and this anterior part of the body exercises greater control over other parts of the body than that found in the worms. This superiority is also evident in improved sense receptors and nerve conduction. The groups of this phylum have a great variety of behavior, which ranges from the permanently attached oyster and the slow-moving clam to the fast-moving octopus and the squid. Chemical sensitivity is present in the tentacles of the snail and scallop and in the sucking discs of the

octopus and the squid. The snail has light-sensitive receptors at the end of the tentacles. The octopus and the squid have eyes that are almost as highly developed as those of the mammals. This has been one of the chief reasons for attributing a high intelligence to these animals. These highly developed receptors and a well-developed nervous system (*fig. 13*) place the octopus and the squid among the highest in intelligence among invertebrates, but their apparent lack of sensory and motor integration does not warrant placing them higher than fishes in psychological standing. The scallops have a row of light-sensitive receptors on the mantle edge near the base of the tentacles. Clams have light-sensitive cells on the inner surface of the siphon. An elongated muscular foot in clams provides locomotion. Sea slugs and snails have a gliding movement caused by waves of muscular contractions on the foot. The octopuses move on the ground by using their tentacles and in open water by jet action of expelled water.

The phylum Arthropoda is a very diverse group composed of almost a half-million species, of which crabs, shrimps, and lobsters are part of a group called "crustaceans." This group lies above the Mollusca in psychological standing because of the existence of a brain and the ladder-type nervous system, which has a pair of ganglia in each body segment. This results in better integration of the parts of the body than is found in molluscs. The head with the specialized sense receptors plays an important part in the animal's orientation. The crustaceans have chemoreceptors in the antennules, or small antennae. These receptors are used to locate food by picking up juices diffusing in water from some distance away. They are also used to detect food by contact. Substrate vibrations are picked up with legs and body. Most of the crustaceans have compound eyes, which are especially well adapted for picking out moving objects.

Fishes

Much of the behavior of the invertebrates is closely related to the extent of the development of their nervous system. In the vertebrate fishes, as well as in the invertebrates, the nervous system is principally a bridge between the sense organs and action equipment, but it is distinguished from the invertebrate system by having a spinal cord, which runs along the back, associated with a much better brain (*fig. 13*). This tubular conductor permits a unification of the action equipment not possible in the invertebrate ladder-type system. Although fishes have this advanced tubular system, they still retain a form of segmental system, which acts like a ladder-type system (not, however, evolutionarily related to the ladder system) and which accounts for some of the stereotyped behavior found in fishes. This segmental system is retained in part by all higher vertebrate animals.

SENSE RECEPTORS OF FISHES IN GENERAL

VISUAL

The eyes have a flattened cornea with a fixed-focus lens. Vision is usually 20–30 per cent binocular because of the position of the eyes on the sides of the

head and each eye is able to move independently. The eyes are able to focus only on near objects. Distance focusing is limited. Fishes have a wide-angle field of vision. Careful experiments have shown fishes to have color vision, but it seems weak. Verrier (1928) found that the structure of the retina does not permit good visual acuity. Acuity seems to be similar to the peripheral regions of the human eye. It allows good vision of movements of objects, but perception of form seems defective. The eyes are used by all fishes to some degree except for a few nocturnal species.

OLFACTORY

Ciliated cells in sacs, which have an opening to the exterior nostrils are able to detect the presence of weak concentrations of chemicals in the water (*fig. 13*). These receptors are used for locating food at a distance as well as for detecting chemical gradients in water. Smell is used to some degree by about half of all fishes.

TASTE

There are many grouped cells with hairlike projections in and around the mouth, on barbels (when present), on growths which hang from the lips, or often covering the body surface. These receptors detect chemicals emanating from food close to the body. The contact taste receptors in the mouth cavity are used for the selection of food and rejection of foreign objects. Some fishes, mainly those that feed by sight, swallow objects without much attention to selection, and often strange objects are found in their stomachs. Taste seems to function in all fishes.

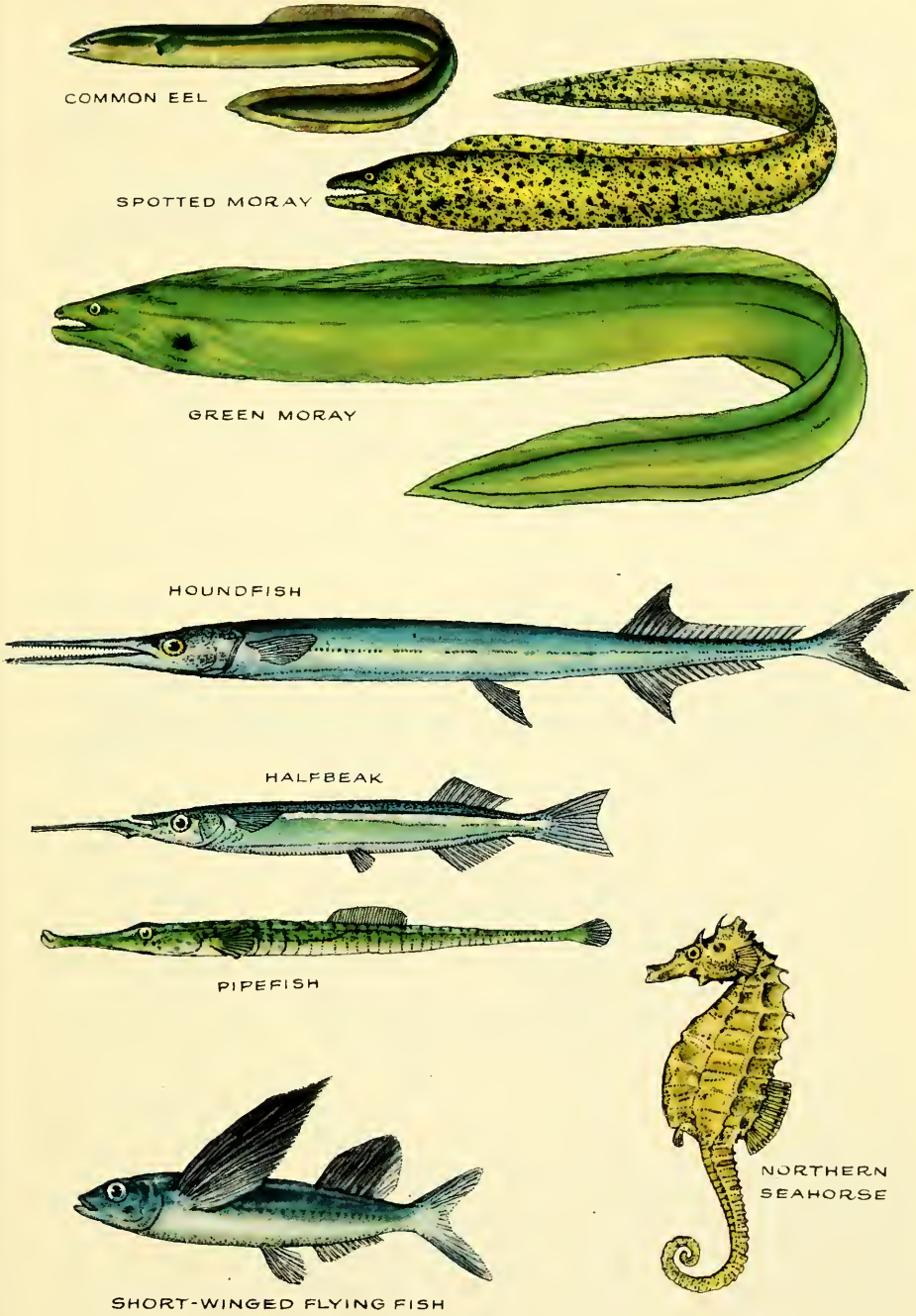
THE LATERAL LINE

Lateral line receptors are composed of ciliated cells clustered at intervals along a lateral line on the sides of the body from head to tail and on some fishes branching on the head (*fig. 13*). These receptors are sensitive to the intermediate vibrations between those perceived by the ear and those perceived by the body surface. While the auditory sense can detect vibrations of high frequency, lateral line receptors can detect only low frequency water movements. Skin contact receptors are sensitive only to solids, water pressure, and very slow vibrations.

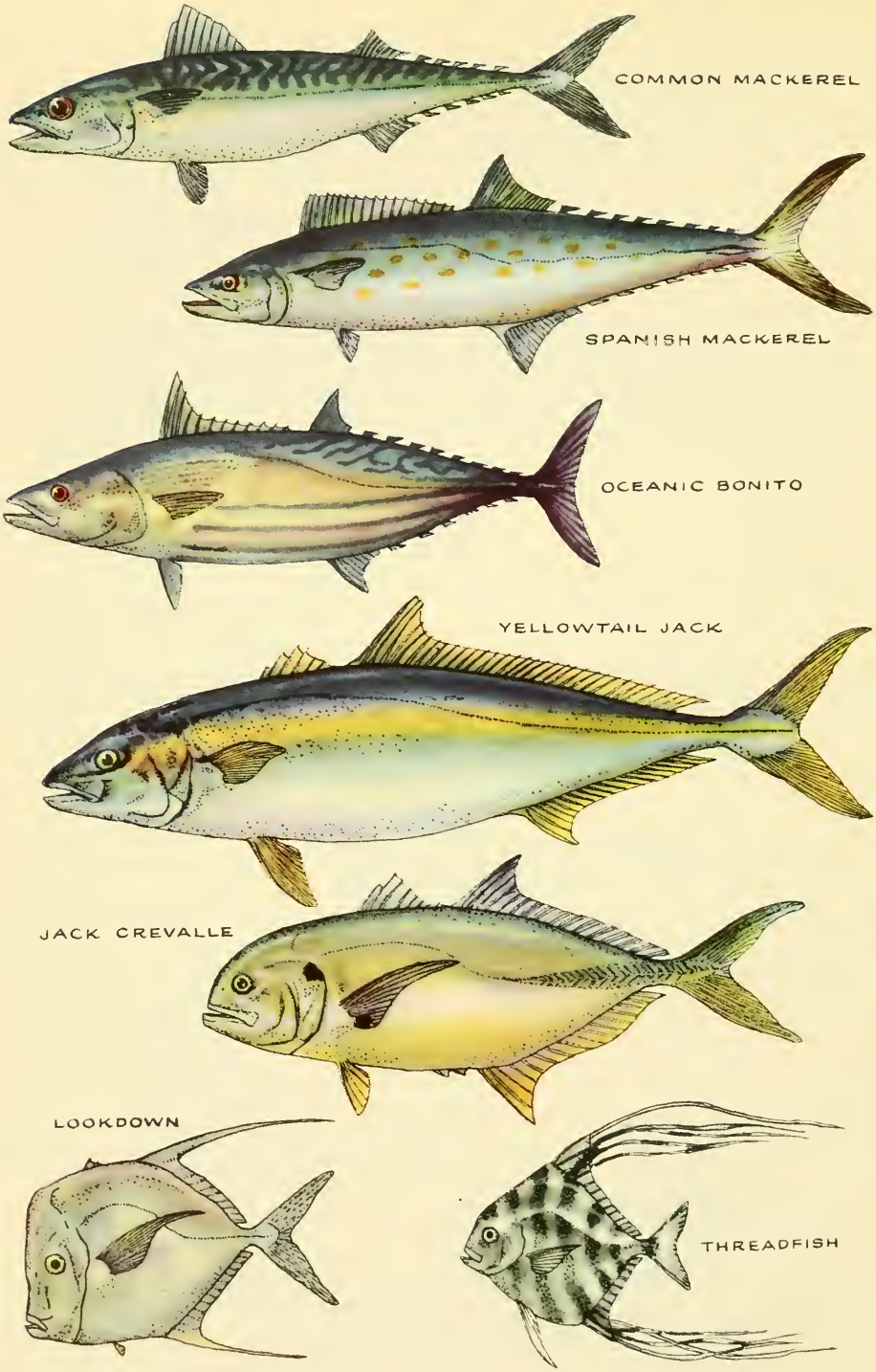
Lateral line receptors are used to locate prey, to avoid predators, and to localize obstructions by detecting direct and reflected water movements. In some fishes at night, these organs become the dominant sensory receptors. They are also sensitive to relative water pressure as well as to direction and rate of flow of water.

AUDITORY

The auditory sense in fishes is poorly developed. However, there is evidence that some fishes can hear sound frequencies of up to 8,000 cycles per second or more. Some fishes are not able to hear at all. The ears of fishes are not visible on the body surface and are used mainly for equilibrium and orientation. It is possible that some fishes use vibrations reflected from the surface, the shore, and the bottom as aids to orientation.



COLOR PLATE 1



COLOR PLATE 2

THE ROLE OF SENSE RECEPTORS IN THE BEHAVIOR OF FISHES

When the environment of fishes is compared with that of land animals it is found that the sea is much less variable than land. The chemical content and temperature of the sea vary little, food is easier to get, and there is no weather as we know it on land (except near shores). This stability of environment requires a smaller repertory of adjustable activities, which accounts for the lack in sea animals (except for the re-entrants) of the advanced psychological organization that is found in the higher land animals.

In spite of the fact that fishes live in a comparatively constant environment, there are a great many types of habitats in the sea—coral reefs, seashores, open sea, and the great depths. Physiological factors such as weak vision, a good olfactory sense, possession of a swim bladder, and well-developed action equipment determine in which of these environments a species will live and a species' environment determines to a great extent its type of behavior.

In the environment of a particular species, the pattern of behavior is to a certain degree determined by the sense receptors it possesses. This close relationship between sense receptors and characteristic behavior is clearly evident in the feeding habits of the rays. These animals have weak eyesight and a well-developed sense of smell and touch; they are for the most part bottom-feeding animals (except the devil fish and the manta), which use their smell and touch organs to locate crustaceans and molluscs in the sand. The jacks are an example of fishes with excellent eyesight, which obtain their food by darting at or hunting down small schooling fishes at the surface.

The important place of sensory equipment in the activities of fishes is pointed out by Jarmer (1928), whose studies show that when a fish is exposed to a visual or olfactory stimulus (depending upon which is its main operating sense), it automatically bites. This is characteristic behavior of fishes in general, resulting from the possession of a primitive type of vertebrate nervous system. In the higher vertebrates, as in the mammals, when one sensory system makes contact with a prey, the animal becomes alerted and other sensory systems are brought into play for a better orientation before striking. These animals have the ability to delay their responses to a stimulus because of their advanced nervous system, whereas in fishes the stimulus brings on a direct and automatic response. An example of this type of behavior is given in the case of the diver who dove into the water within a few feet of a barracuda, a visual feeder. The fish turned instantly and struck the swimmer at the moment of the splash. Approached underwater, the same barracuda would probably do no more than show curiosity. The diver's splash and movement resembled the splash and movement of the prey of this fish, that is, he resembled the characteristic visual feeding stimulus, the splashing at the surface of a wounded fish or of schooling fish.

The stereotyped visual feeding behavior of the barracuda was demonstrated when the authors placed freshly killed fish on the bottom near a barracuda, resulting in no feeding response. But moments later when a moving, wounded fish was presented, the barracuda swiftly struck. A shark with weak eyes and a strong sense of smell, on the other hand, would have reacted readily to the smell of the dead fish on the bottom and also to the wounded, moving fish. Consequently, an excellent method for understanding fishes' behavior is to group them according to the way they secure their food. They generally fall into two

groups—the visual feeders and the chemical feeders (mainly through sense of smell)—with one system dominating consistently.

1. Chemical Feeders. The chemical feeders, such as the mullets, rays, and most sharks, among others, usually have poor eyesight, but they have a well-developed olfactory sense supported by touch and taste organs, and these are used to locate bottom life and carrion, and to sift organic matter from the bottom.

   The olfactory system is a general "exciter," which increases searching activity around the area where the scent is detected, and as the fish gets nearer to the source of the scent, the paired olfactory organs direct the fish to the food. Vision and the contact sense probably come into play in the immediate vicinity of the food.
2. Visual Feeders. Many species of fishes respond more to the visual stimulation of a moving object than they do to chemical stimuli (barracuda, bluefish, tuna, cod, blennies, etc.). These are the fishes that pursue their prey, and vision is the dominant sense used in making contact with their environment.

   These fishes, upon immediate sighting of a moving prey or preylike object across their fields of vision, respond with a compulsive and direct strike. This response appears only when the prey lies within the field of visual acuity of a given species, an acuity which in fishes is generally limited to short distances. The eyes and body move simultaneously, as if sighting and striking were one movement, so powerful is the role of vision in these species. The voracious bluefish is a good example and is well known among fishermen for striking at any object that falls within its visual field. The eyes have a rather powerful, direct and stereotyped influence on behavior in the visual group, almost always producing the biting response, whereas in the chemically dominated group, olfaction plays the part of a general exciter and accounts for less stereotyped behavior.

The other sensory systems generally support the dominant systems, but they may take the place of chemical or visual senses as the dominant sense under some conditions; for instance, at night or in murky waters the lateral line receptors often become the dominant sense. These exteroceptive systems in fishes generally work independently with little intersensory integration.

In the behavior of the higher vertebrates, such as some amphibians, reptiles, birds, and mammals, no one sensory system dominates consistently in the way that fishes' behavior is dominated by vision or olfaction. One sensory system, when stimulated, brings another system into action with overall integration of activities. Bringing other sensory systems into play requires more time, gives a better orientation to the stimulus, and allows greater flexibility in responding, enabling the animal to make a better and wider adjustment to its environment.

CHAPTER 3

MAN AND THE SEA, I—Photography and Equipment

UNDERWATER PHOTOGRAPHY

This section has been written to help the underwater swimmer to explore, document, and enjoy underwater life. With photography as a tool, the swimmer can better identify the different species that swim about him as well as make possible contributions to science.

The aesthetic aspect of the underwater world has been one of its greatest attractions, an attraction that is hard to describe. Only through photography can it be brought to the surface. One has only to see coral, which takes endlessly exciting formations, and the angelfishes, which are the colorful ballerinas of the underwater world, to realize the possibilities for taking artistic photographs. The graceful movements of schools of fishes as they swim about the reefs, the birdlike flying of the rays, and the sleek beauty of sharks as they move through the water—all make fascinating pictures.

There are startling nature photographs to be taken: the gigantic whale shark standing on its tail feeding on plankton, the manta ray leaping out of the water as it drops a newborn in midair and heralds the birth with a thundering slap as it hits the water, the parrot fish standing on its tail with its mouth open while little wrasse clean its teeth and face by eating the food particles left there. There are hundreds of similarly interesting instances in the lives of sea animals yet to be recorded on film.

Effects of Sea Water on Light

Underwater photography is mainly for clear waters. Ideal locations are tropical waters such as those surrounding the Bahamas, where visibility is sometimes better than 100 feet. Excellent photographs can be taken, however, in waters with visibility of 15 feet or better. Water conditions which allow visibility less than 15 feet limit picture taking to close-ups.

Penetration of sunlight into the sea is limited by the roughness of the surface, the density of water, and the turbidity caused by the presence of organic (planktonic) and inorganic (silt) particles. These particles cause an effect called "scattering," which tends to make pictures taken under water at

a distance lack contrast and three-dimensional effect. This is similar to shooting pictures in a fog. Because of scattering, the camera should be as close to the subject as possible in order to obtain sharp contrast.

Sea water also has the effect of absorbing colors differentially, the red end of the spectrum suffering the greatest loss. The deeper sunlight penetrates, the greater the loss of colors. The deterioration of color from the surface to the depths in clear water is as follows (for photographic purposes): At about 3 to 4 feet from the surface, red begins to disappear noticeably; at 15 feet so little remains that photographs taken without filters show no red. Orange goes out at about 30 feet, yellow at about 65 feet. Below 65 feet only green and blue remain, until at approximately 1,800 feet all light visible to the human eye disappears. These figures are approximate and dependent upon water conditions. (Chapter 1.)

Exposure Under Water

Exposures under water depend upon surface conditions, the type of bottom, and the turbidity of the water. Because of turbidity, light-meter readings are more accurate the closer the subject is to the meter; the greater the distance, the less reliable the reading. In shallow water with only one kind of bottom (e.g., sand) generally one reading is sufficient for all exposures as long as the surface conditions remain the same. Clouds and water currents that stir up particles are factors that change lighting conditions.

In calm water only about 3 to 4 per cent of the incident light is lost because of reflection, but choppy water results in a 20 to 30 per cent loss in intensity at 2 or 3 feet below surface. On bright calm days in clear waters, exposures at about 5 feet below surface are almost the same as above the surface. To 30 feet, use a meter or increase the lens opening one more stop. A direct-reading light meter (Weston) can be mounted in an underwater housing in line with the lens for constant readings.

Shutter speeds under water are generally the same as above water. A general working shutter speed is 1/50 to 1/100; for static subjects (e.g., coral) 1/25 may be used for increased depth of field, provided the camera is not in motion. The success of increased shutter speeds for taking fast-moving objects is somewhat limited by the low light-level conditions.

Camera

Under certain conditions any type of camera can be used to take underwater pictures, but the most successful underwater pictures are taken with the camera arrangement which reduces mechanical handling to a minimum. This allows the photographer to take advantage of opportunities and to concentrate on safety and subject. These are important considerations when one remembers the equipment the swimmer has to carry, the constant motion, the attention that must be paid to safety, and the time element involved in use of the aqua-lung. Also, if an exciting specimen swims by, the swimmer with an ordinary camera could not take more than one picture if he had to struggle with setting the shutter speed and lens opening, cocking the shutter, and advancing the film. Another factor operating to complicate picture taking is that the reaction time

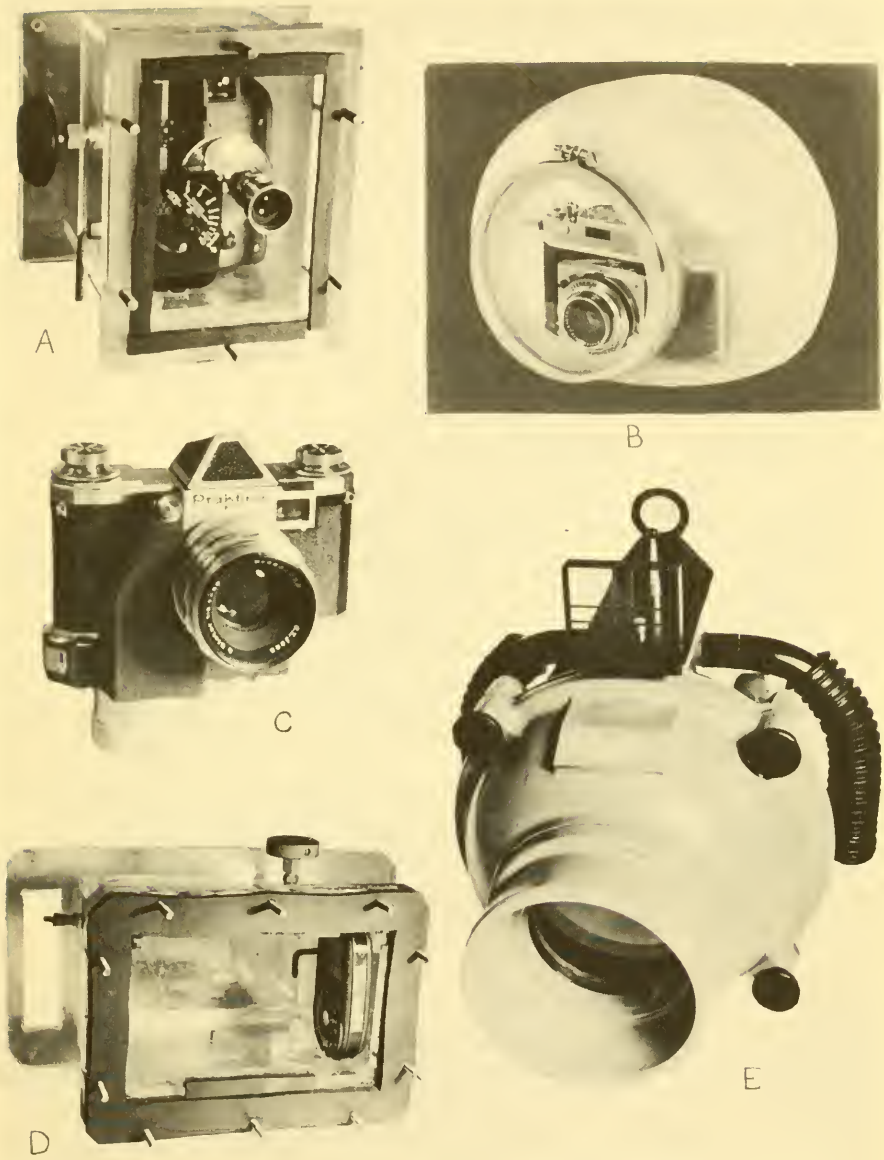


Fig. 14. Underwater photographic equipment. (a) *Plastic housing for DeJur Spectator 8mm. movie camera and Weston Direct Reading exposure meter.* (b) *Inexpensive Voit plastic camera bag for beginners.* (c) *Praktina 35mm. single-lens reflex camera with rapid sequence spring motor.* (d) *Plastic housing for a 35mm. single-lens reflex camera with a Weston Master exposure meter.* (e) *Cast metal housing for Robot 35mm. rapid-sequence camera. The plastic cases were assembled by plastics dealer and the controls added by the authors at a total cost of less than twenty-five dollars for each case.*

of fishes and most marine animals (about one twenty-fifth of a second) is faster than that of humans. This means that if a photographer and a fish sight each other at the same time, the fish could be at least halfway turned around and headed away before the photographer raised his camera.

The 35mm. camera is widely accepted as the camera best suited to underwater work. Both camera and case are small and easy to handle. It takes a thirty-six-exposure roll of film, enabling the photographer to take fewer trips to the surface to reload. Some 35mm. cameras have bulk loading attachments which take up to four hundred frames. There are 35mm. cameras available which have a spring mechanism that transports the film and cocks the shutter, leaving only the trigger release to be pressed for rapid sequence exposures. The Praktina (*fig. 14*) and Robot meet all these requirements.

Movie Cameras—For Underwater Use

When selecting an 8mm. movie camera, one should:

1. Select a camera with an f/1.9 normal and f/2.5 wide-angle lens.
2. Select a camera which has the longest film run possible on one winding (e.g., 10 feet). Long scenes are effective, short scenes are meaningless. A long film run cuts control manipulations and allows concentration on the subject. A good example of such a camera is De Jur (*fig. 14*).
3. Select a camera you know won't jam in the middle of an important scene necessitating a trip back to the boat to clear a jam. Jamming is time-consuming, troublesome, expensive, and results in the loss of previously exposed film.

The factors which determine the selection of a good 8mm. camera for underwater work also apply to the 16mm. camera. The 16mm. camera should load the largest footage possible; short footage cameras mean many trips to the surface and loss of opportunities. Many of the professional photographers use motors attached to their 16mm. cameras to eliminate hand winding.

The Use of Wide-Angle Lenses Under Water

With both motion-picture and still cameras, a wide-angle lens is necessary when one wishes to encompass larger subjects without having to shoot at great distances.

Because of the refraction of light through glass, air, and water, objects under water appear one-third larger or underwater distances appear one-fourth less. This affects the goggled eye as well as the camera, making it necessary for the photographer to back off farther to fill the picture frame and to set the focusing scale at 75 per cent of the actual distance. The wide-angle lens helps overcome this by permitting the camera to be taken closer to the subject. The lens offers another advantage in that it has a larger depth of field, which means one can shoot almost without changing focus. This is highly desirable, considering that most underwater pictures are taken at a low light level which calls for

wide apertures—resulting in lower depth of field. It is important when selecting a wide-angle lens for scientific work that there be no distortion at the edges and corners—the type of distortion found with some extreme wide-angle lenses. This distortion is acceptable for amateur work.

The Normal Lens and Underwater Close-up Photography

There are all forms of interesting life—coral, crabs, small reef fishes, plantlike animals, etc.—that require close-up photography. Most camera range finders are useless under water, but single-lens reflex viewers for critical focus give a large enough image to be useful.

The depth of field at short camera-to-subject distances is slight (even with small apertures) and a miscalculation of only an inch or two is enough to cause out-of-focus pictures. (A workable rule for determining depth of field for any aperture is one third the distance in front of the subject facing the camera and two thirds behind.) The wide-angle lens is desirable for photographing large marine subjects, but it necessitates that one get close to the subject in order to fill the negative. This lens is not effective when working close to small moving subjects; small reef fishes are generally skitterish when approached closely, within a few feet, and swim off or become hyperactive. The use of a reflex camera equipped with a normal lens set for distances of 18 inches to 3 feet gives a slight telephoto effect allowing the photographer to back off so as not to disturb the subject yet fill the negative. This is contrary to the general belief that only wide-angle lenses are suitable for underwater work.

With nonreflex cameras a measured stick is useful to determine distances when photographing static life, but drives off the active life. Since most small fishes are constantly moving about a small area around the reef, a ruled stick can be used to determine probable distances where the subjects have a good possibility of appearing. This involves studying subject behavior before shooting, but it can be very rewarding. Keep in mind that the yardstick appears one third longer under water.

Color-Correcting Filters

Color correction filters will function to a depth of approximately 50 feet. Beyond this depth in most waters not enough of the remaining red, orange, and yellow light is left (because of the effect of selective absorption, scattering of light, and lack of intensity) to make filtering practical. Some source of artificial light is necessary to restore color below this depth. There are shallow-water photographers who feel that filters are unnecessary and that the blue-green effect is desirable and truly representative. This is a matter of individual preference. The authors feel that the complete elimination of the blue-green effect results in the loss of the unique color tones of the underwater world and prefer the use of filters which do not completely eliminate this effect.

For waters that tend toward blue with little green use a CCR series (color-correcting red) filter. If the water tends toward yellow, that is, has a definite green tinge, use a CCM series (color- correcting magenta) filter. For a clear tropical

waters like the Bahamas the authors prefer CCM #20 or #30. These filters will give an overall balance of color with a slight blue-green effect without introducing a large filter factor. Be sure to include the filter factor along with the exposure meter reading to get your camera exposure setting. For instance, the filter factor for a CCR #30 filter is 1.8.

Black and white pictures show increased contrast if a filter of the series CCY (color-correcting yellow) is used. A CCY #10 or #20 is adequate for most waters. All these filters are available in gelatin sheets at low cost, and they may be cut and mounted on the back or front of still or movie lenses, or pasted on the inside of the camera case in front of the lens. When using filters and a meter it is possible to put the same filter over the meter to eliminate exposure computation involving filter factors.

Film

Films for underwater photography are the same as used above water. Considering that most underwater lighting conditions are of a low light level, the best color films are the faster speed Anscochrome and Ektachrome. Ektachrome gives good results, but Anscochrome gives better color rendition under water. The exposure latitude is one stop under and over ideal exposure for good color rendition.

Black and white films have a wide exposure latitude with three stops above and below ideal exposure giving a workable negative. The best films are Panchromatics with an ASA 50 emulsion speed or better. For caves and poor lighting conditions found near reefs, take advantage of the faster speed films. However, increased speed of film usually results in increased graininess which cuts usability when enlarging.

Any color film like Anscochrome 16mm. reversal movie film that has an ASA 32 rating and gives excellent color rendition at low light levels is well adapted for underwater use. This film allows the underwater photographer to use smaller lens openings and to shoot under conditions which formerly did not allow color. Anscochrome reversal film allows a latitude of one stop over and one stop under ideal exposures.

Thin emulsion black and white films have extremely high resolving power, very fine grain, and fair contrast which make them good for underwater work. The exposure latitude of thin emulsion films is about the same as ASA 32 color films.

Film manufacturing is undergoing great changes to which the underwater photographer should be alert.

Artificial Lighting

There are tremendous photographic opportunities in waters shallower than about 60 feet for the amateur and the professional. Below 60 feet, in caves, and where poor lighting is found, artificial lighting units such as flash attachment and strobe light units that can be converted to underwater should be used. These units can bring light and color to the blue-green depths. It would

take many pages of technical information to go into the techniques of artificial lighting in deep waters. There are excellent books devoted to the subject. (See Bibliography.)

Underwater Camera Techniques

A good technique to ensure not missing any opportunities when exploring is to take along two cameras, one in hand and the other hanging from a neck strap. Each camera might be set for special work: one set at 1½ feet to 3 feet for close-up work and the other set for distance shots; one with color film and the other black and white; one a still camera and the other a motion-picture camera. It is a frustrating experience to have a camera loaded with black and white film when a good color situation presents itself

Whenever possible, avoid shooting into open water, but try to frame subjects with a reef, coral, or a school of fish. Pictures of fishes with people in the background are also interesting and show relative size. Special effects are obtained when subjects are shot against the surface or with back lighting. Generally the best results are obtained with side lighting. Get as close to the subject as possible to avoid pictures without contrast. Underexposing slightly and overdeveloping negatives will increase negative contrast and permit the use of a smaller lens opening for increased depth of field. Sunshiny days are best for color, and then around midday. Avoid fogging and light streaks in the film by reloading in the shade or, if in an open boat, under a canvas or towel.

The lack of gravity experienced under water permits all sorts of special camera effects equal to the most expensive studio setups. For example, by using the feet for propulsion and handholding a movie camera, one can get a dolly effect as well as all sorts of angle shots.

For an exciting experience as well as a method that affords wonderful photographic opportunities, put on an aqua-lung with extra weight, and sit on the bottom in an area where there is much life. As soon as the fishes come to see you as an unthreatening part of their environment, they will swarm around you with curiosity or completely ignore you, allowing you to study and photograph them in their natural state.

Underwater photographic technique is by no means standardized. There is much that the photographer can still do toward evolving new techniques.

Underwater Housings

In order to take pictures under water, it is necessary to have a watertight case for your camera. If you own one of the more popular cameras, such as the Robot, Ditto, Leica, Argus, Rolleiflex, Contax, Nikkon, or Canon, there are manufactured cases available. (Write the manufacturer of your particular camera for information.) Inexpensive camera arrangements for the beginner are shown in figure 14. Many photographers build their own cases because of the expense of manufactured models and because many cameras do not have cases designed for them.

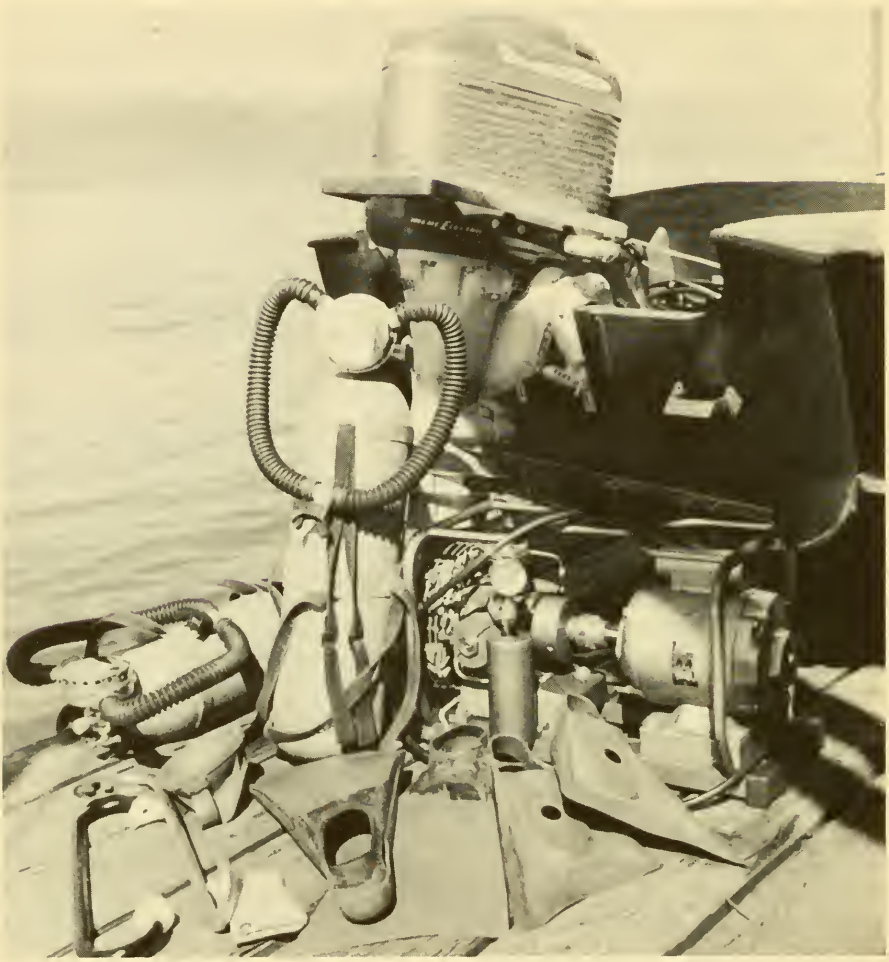


Fig. 15. Some diving gear for snorkeling and self-contained diving. Snorkel tubes, mask, emergency air pack, and flippers are in the foreground. Aqua-lungs and air compressor for filling tanks are shown in the rear.

DIVING GEAR

Basic Equipment

The basic equipment necessary to start underwater exploring includes swim fins, mask, and snorkel. The mask or goggles is a must, for the eyes see everything out of focus without it. One must constantly keep in mind that the mask makes objects appear one third larger or distances one fourth smaller. The mask should fit comfortably, allow maximum vision, and not leak water. The flippers, or swim fins, will greatly increase swimming ability and speed as well as free the hands for photography and safety. They will also give better balance and maneuverability. The fins should feel comfortable—if too tight they will

impede circulation, leading to cramps. An allowance of an extra size should be made if one plans to use a full rubber suit that covers the feet.

The snorkel tube (*fig. 15*) is usually made of plastic, rubber, or metal. It allows the swimmer to breathe surface air with the head under water and the eyes out of the sun. One of its important features is that it permits the body to float just a few inches below the surface at the point the body would normally be in a dead man's float. Consequently, little energy is expended in keeping afloat as compared to treading water without a snorkel. Thus, the swimmer can swim great distances without tiring. The snorkel is a very simple device to use. The valveless tube is used by the experienced swimmer and the ball-valve type by beginners. A good technique for almost doubling your breath-holding time under water is to take many quick, deep breaths before taking the last one for the plunge; this rapid breathing before diving builds up oxygen in the blood.

Safety under water, as in all other activities, works best when it is an attitude rather than a set of rules, for trouble can come from unexpected directions. Keep on the alert for the unexpected.

The diver should carry at all times a very sharp, double-edged, pointed knife for emergencies. He should also carry an emergency air pack (underwater parachute), which, responding to a squeeze, will inflate, take the diver to the surface, and keep him afloat.

The Aqua-Lung or Scuba

This self-contained underwater breathing apparatus gives the swimmer almost all the freedom that a fish experiences. It allows the diver to go into deeper water with little effort, without the need to surface for air. It is useful to the naturalist and especially useful to the photographer, for he can sit and wait for opportunities. (Figure 131, the "kissing" grunts, was taken after one of the authors remained still on the bottom at 35 feet for almost three quarters of an hour.) The experience of using the aqua-lung in clear waters, abundant with marine life, can be one of the most memorable in one's life. It can also be the last. It is such a simple device to start using that the novice can easily get himself into trouble. The authors recommend strongly that no one attempt to use any self-contained underwater breathing apparatus without at least six hours' training under competent instruction. Besides instruction on how to use the lung, a portion of the six hours should be devoted to the part water pressure plays in the aqua-lung's operation and to the effect of pressure on the body. A beginner would be wise to start with the snorkel, which will make him conscious of his breathing, then move to the aqua-lung.

BASIC SAFETY RULES

1. Never dive alone; use the "buddy" system, and keep within sight of each other.
2. Plan in advance what is to be done in an emergency. Be sure all members of a diving party know the technique for executing the back pressure-arm lift method of artificial respiration.

CHAPTER 4

MAN AND THE SEA, II—Dangers and Chumming

DANGERS OF THE SEA

When one thinks of dangers of the sea, sharks, barracuda, moray eels, and other large, predatory animals immediately come to mind. These animals can be dangerous, but they are not usually every man's greatest danger in the sea. Dangers come from two sources primarily, from within the diver and from the sea. By far the most potent of these dangers are those that derive from within, for the diver can carry within himself the attitudes and knowledge that make the sea, like an automobile, either a safe or dangerous place.

The diver must develop an attitude of safety and respect for the sea which involves thorough knowledge of equipment (Chapter 3) and a resolve never to dive alone or out of sight of other divers. The diver should take every precaution that his equipment gives him every bit of advantage possible.

The diver must have a knowledge of his own physical limitations which involves the general principles of diving physiology (bends, nitrogen intoxication, squeeze, lung collapse) and the peculiarities of his own body. This knowledge will keep him from the overconfidence which would lead him into situations beyond his ability to handle.

The diver must equip himself with a knowledge of the sea's inhabitants, their identification, habits, and adaptations to their environment. This, of course, implies to a certain extent that the diver is often free from possible injury from the life of the sea to the extent that he is skilled in biology. One of the diver's most common errors is attaching such anthropomorphic qualities as cowardice to animals of the sea. This is a fundamental and even dangerous mistake in trying to understand behavior patterns and mentalities very different from our own. One of the important dangers that comes from within is fear, which leads to panic or even immobilization of the diver. This fear usually arises from misinformation and lack of understanding of the sea and its life. Consequently, the way to eliminate fear is to know and understand the sea, in which environment the diver is a misfit, able to exist only in a highly organized state. Even with his technology, the diver moves under water with disadvantages and fears similar to those which primitive man experienced in the Stone Age, being subject to similar dangers from the elements and from wildlife. Man's real

superiority in the sea, an environment which for him is foreign, is not physical, but is psychological and intellectual, for the physical elements of this environment prohibit man from being as effective in the sea as he is on land.

It is not the authors' intention to review the life of the sea minutely for dangerous species. This would require a book in itself (see Bibliography). Instead, the following is a review of the ways in which animals and plants are dangerous, with examples of each. The usefulness of this review depends a great deal on the common sense of the diver. For example, a complete list of all fishes with sharp spines, sharp gill rakers or heavy teeth would include most of the fishes in the sea. The diver must use his own judgment when handling these fishes.

Details of the dangers of the species mentioned are described in Chapters 7 to 10.

Passive Dangers

STINGING, IRRITATING, BITING, AND SPINY ANIMALS

Most dangers in the sea are passive ones, such as fire coral and the poisonous spines of some fishes, which become dangerous only through the actions of the diver. It is a good rule *never to touch any plant or animal which cannot be properly identified. Wear gloves.* The dangers from stingers, poisonous spines, etc., exist in a very great number of species. Usually, such mechanisms are used as modes of defense by these creatures, though in some cases they are also food-getting mechanisms, such as the tentacles of the Portuguese man-of-war or those of anemones. But in all cases, man plays the aggressor, and therefore he can almost completely control this aspect of danger merely by knowing where the dangers lie. A good example of this is the case of the diver who, having caught an octopus, slung it over his shoulder and was bitten on the back as he carried the octopus up the beach. He died from the poisonous bite in a short while. He was the victim of the now popular belief that octopuses are harmless.

There is a huge array of species spread throughout most of the phyla of the animal kingdom that can sting or injure with spines and claws. Some of these species advertise their harmful parts, but some do not. On the whole, spines and stings are defensive in purpose and do not cause serious injury, but a few are very dangerous. For this reason the very dangerous species are listed separately.

Dangerous examples:

> Portuguese Man-of-War; Lion's-mane jellyfish; Sting rays; Eagle rays; Chimaera; Scorpion fishes; Sea snakes; Octopuses; Squids.

Less dangerous examples:

> Red tide protozoan; Fire sponge; Poison-bun sponge; Many sponges with sharp spicules; Many coelenterates with large nematocysts, including some hydroids, anemones, and fire corals; Parasitic flukes which cause "swimmer's itch"; Bristle worms of several species; Biting worms such as *Nereis;* Cone snails; Sea urchins; Crabs and lobsters with strong spines or claws; Spiny

dogfish; Bony fishes with strong teeth such as the toadfishes; Bony fishes with fin spines such as catfishes; Bony fishes with opercular spines such as the squirrel fishes and the angelfishes.

This list covers almost all the species that can be dangerous to the diver. However, judgment and common sense are the best guides for handling most animals with spines, claws, or teeth. Many fishes have spiny gill rakers inside their gills which can inflict cuts when handled.

ENTANGLEMENT AND ABRASION

In extensive beds of algae, particularly kelps, it is fairly easy to get dangerously entangled in these long, tough plants. Several corals are very sharp and can inflict cuts that are painful, liable to infection, and slow to heal. The reason for the slow healing and extra pain of coral cuts is not known. Any cut that bleeds freely should be attended to at once because of the danger of infection. A diver, simply for safety's sake, should not remain in the water if bleeding because of the danger of sharks. The diver must use his own judgment in this area, staying away from kelp and branching coral or rocks in rough water.

POISONOUS FLESH

Almost all animals of the sea are good to eat, but the flesh of some can produce results varying from an upset stomach to death. The maki-maki or "deadly death" is a Polynesian species of puffer fish with extremely virulent flesh. Fortunately, North America is relatively free of species with poisonous flesh. The poisonous parts may either be the muscles or some other organ of the viscera such as the liver, gall bladder, or reproductive organs. It is sometimes rather difficult to trace down what organs of an animal are poisonous or under what conditions a normally nonpoisonous species may become poisonous. For instance, some species, such as the yellow-fin grouper, barracuda, and various jacks among others, have poisoned people, but very little is known of the causes responsible for this. It is suspected that these fish sometimes eat the flesh or eggs of poisonous fishes. This is a subject about which very little is known. Because more and more animals of the sea are being used for food, this subject is becoming very important.

Some well-known examples of poisonous animals:

Many filter-feeding clams and oysters (they become poisonous in the warm months due to accumulation of toxic plankton in their digestive tracts); Six-gilled shark; Chimaera; Escolar; Some triggerfishes; Some filefishes; Most puffers (Chapter 9—Plectognaths); All porcupine fishes and boxfishes.

Active Dangers

THE AGGRESSIVE SPECIES

These are few in number, and each of these is considered in detail individually in later chapters. All predators are aggressive for food and will attack only if the diver falls into their feeding patterns, which usually he does not. Many of these animals can be driven off by taking the psychological advantage and swimming toward them (with the exception of the killer whale).

Anything the diver does that resembles the normal prey of these predators might cause them to bite. For example, blood in the water stimulates sharks into a nervous frenzy called the "feeding mood" so that they will bite at anything in and around the area scented with blood. The smell of blood leads them to the prey, and when the victim or any object comes into range of their poor eyesight they will almost always bite. This is a normal feeding pattern of most sharks, which have a highly developed olfactory sense. For that reason, carrying dead or wounded fish on a belt while swimming can also be dangerous.

Many fishes feed mainly by sight, and those dangerous to man are usually the faster-moving fishes such as the barracuda. They usually hunt down their prey with quick, darting strikes. Any splashing about the surface, especially in water with poor visibility, may resemble a school of frightened fish or a wounded fish, causing barracudas or other fishes to strike blindly. This is almost like a reflex with them (Chapter 2). Such fishes as wahoo or tarpon might possibly become dangerous in the same fashion.

Bright, shiny objects such as rings or belt buckles look like the bright side of some fish and attract predators. When fishes are hurt they often show their light undersides. Having objects or clothing that flutter as the diver moves through the water can be dangerous for the same reason.

Diving at night or in water with poor visibility can be extremely dangerous because many fishes such as sharks and fishes that would not normally attack man do so under these conditions (barracuda, Chapter 9, and sharks, Chapter 8). Here again, the diver enters the feeding pattern of fishes, for many fishes locate prey at night by picking up vibrations of swimming movements with their lateral line receptors (Chapter 2). These fishes pick up the vibrations of prey moving through the water and strike in the direction from which they are emitted.

Some fishes have chemoreceptors on the skin of the body, and it is possible a touch by a diver will emit a biting response in the direction of the touch.

Of course, almost all animals on land or sea when cornered or wounded will fight with every ounce of their strength. When a diver reaches into a hole for a lobster there is a chance that he will be bitten by a moray eel. The eel sees this move as an aggressive action and bites to defend itself. Toadfishes and wolf eels can also be provoked into biting in this way.

The killer whale, being an intelligent mammal, must be viewed apart. It is particularly dangerous because of its liking for larger warm-blooded prey. Luckily, it is rarely seen out of cold northern waters. Almost nothing is known of its reaction to man under water.

Aggressive animals dangerous to man:

Some sharks; Large moray eels (when molested); Barracuda; Killer whale.

Other large predatory animals which might be dangerous if man enters their feeding pattern:

Sawfish; Tarpon; Spearfishes; Giant jewfishes; Wahoo; Some other large predators.

LARGE SPECIES

The size and power of some marine animals should be a deterrent to handling them or being careless in their presence. Since the sea is an environment to which they, not the diver, are adapted, all animals of large size must be respected. The best defense upon meeting large animals under water is to let these animals see you as part of the environment and to move slowly and without alarm. Here, as in aggressive species, taking the psychological advantage and swimming toward them will usually drive them off.

Possibly dangerous large animals:

Large squids; Large octopuses; Whale shark; Basking shark; Manta ray; Other large sharks and rays; Tarpon; Tuna; Spearfishes; Large groupers; Jewfishes; Sea turtles; Seals; Sea lions; Porpoises; Whales.

CHUMMING—ATTRACTING ANIMALS

In most places, the majority of the animals of the sea are remarkably unafraid of the diver because, until recently, he has left them comparatively unmolested. In areas where spearing is done, fishes have become wary and difficult to approach. For purposes of photography and observation, chumming is extremely useful in attracting the wary and tame alike. Eventually, with periodic feeding, quite quickly in fact, fishes and other more intelligent animals learn to recognize their benefactors. It is a great thrill to be able to establish harmony with the animals of the sea by chumming them.

Very little is known about chumming. New techniques, methods, and subjects should constantly be tried. It would be just as well not to try to chum sharks, manta rays, huge jewfishes, or barracuda by feeding methods, but almost all others, including sting rays, which have been known to be able to recognize their feeders in captivity, might be tried. Chumming of very small fishes such as wrasse, blennies, and gobies is very rewarding. Three general methods of chumming may be used:

1. Feeding. Good chum may be prepared from a mixture of sand, bread, and shrimp. In place of shrimp, various other sea foods may be used, but red meat is not successful because it bleaches out in water. Natural foods such as broken sea urchins, shellfish, and large crustaceans are also successful. The first step is to get fishes to eat in the presence of the diver—chumming the area. If the diver is to be associated with the food, it is important that the time between presentation of food and eating be as short as possible and also that presentation of food be made often. Eventually, the subject will be following the diver about, waiting for more offerings. Groupers are particularly good subjects of this method. Morays are somewhat less "friendly" subjects, food placed near holes in reefs usually producing one or more of them. Great masses of smaller fishes such as wrasse never fail to accept food vigorously.
2. Sounds. This is a subject about which very little is known and about which critical experimentation is yet to be done. Mullets are known to be attracted by bells. Croakers and grunts might respond to an imitation

of the noises they make. Porpoises communicate by sounds under water and could probably be attracted by imitating them.

3. Movements. Smooth, regular movements will attract very little attention under water, but jerky, splashy movements are known to scare most fishes away and to attract such large predators as barracudas and sharks. The clever use of body movements can serve to attract some fishes. The authors used retreating movements to attract barracudas for photographic purposes. The same have been known to elicit the curiosity of groupers. Small fishes such as blennies and demoiselles are often attracted by wiggling fingers. Movement is another area about which little is known.

CHAPTER 5

EVOLUTION, NAMES, AND CLASSIFICATION

As the swimmer explores the underwater world, he soon becomes aware of the diversity of shapes, forms, and habits of marine life. The bizarre shape of the sargassum fish, the sleek beauty of the tuna, and the plantlike form of gorgonians lead him to wonder what their relationships are, both to the environment and to each other. The adaptation of each of these to their environment depends upon the many small hereditary changes which, if advantageous, allow them to find food more easily, breed more successfully, or live longer. This adaptation involves evolution.

EVOLUTION

Figure 16 gives in "tree" form an outline of evolution of fishes for the last 400 million years, the period of time that their evolution is known through paleontological studies. No more than the barest summary of the evolutionary process from which the tree took root and grew can be given here. (The excellent books noted in the Bibliography, especially Simpson's *Meaning of Evolution,* should be consulted for further information.)

The basic unit in evolution is a *population,* all members of which have free access to all other members without spatial, ecologic, social, or any other barriers. Take, for example, a hypothetical isolated coral reef, over and around which swim several individuals of a certain species of butterfly fish. These individuals compose a single population; all of them could breed freely together if they so chose. This population may be thought of as possessing a number of characters, hereditarily controlled by *genes,* in common. That is, the population represents a common *gene pool.* Because all members of the population breed together and share genetic features in common, they would not be likely to differ from each other significantly, perhaps only varying slightly in size or intensity of coloration, etc.—differences due to the possession of slightly different assortments of genes from individual to individual. Butterfly fishes, for example, show variations which are due to different gene assortments. For instance, members of a single population may have eye stripes of varying widths and

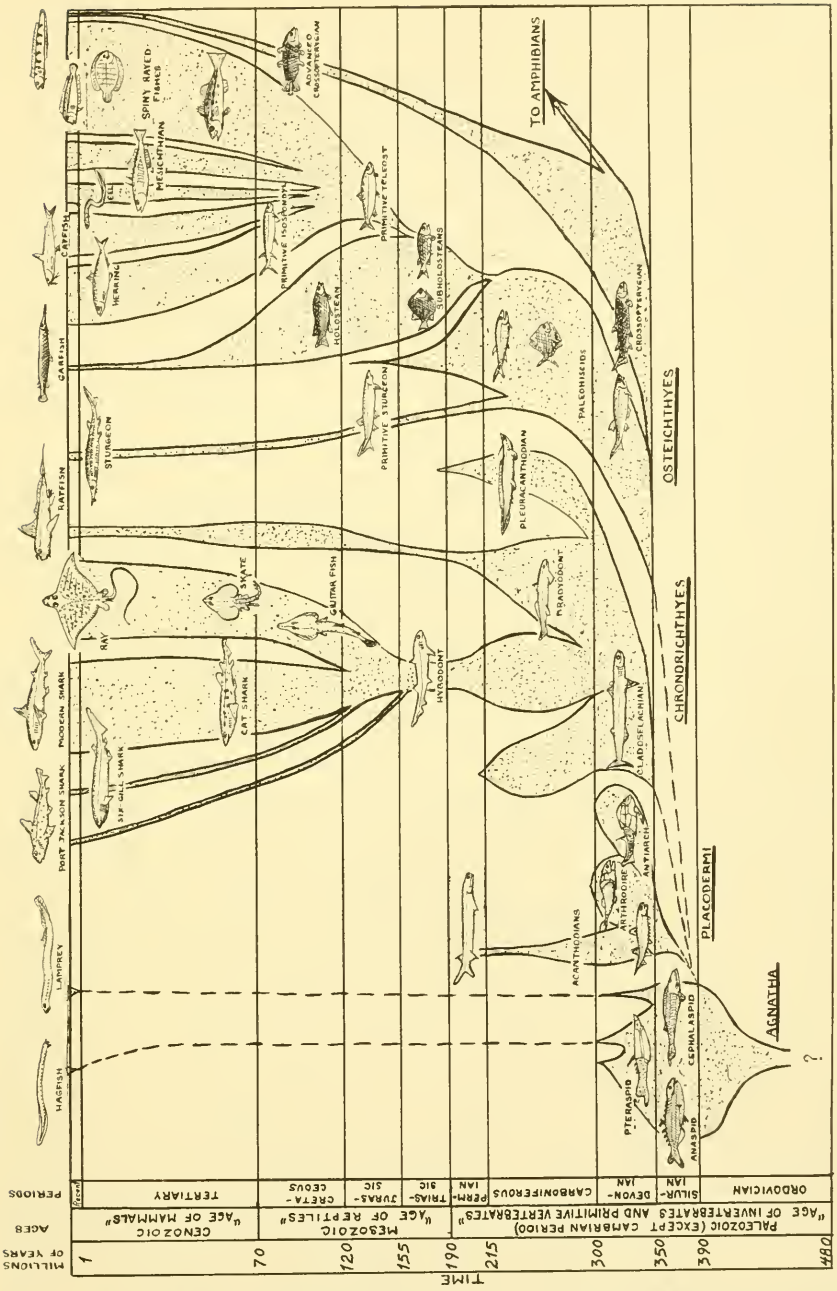


Fig. 16. The evolution of fishes. The stippled areas are approximately proportional in size to the numbers of species in each group. Notice that the more advanced groups tend to replace more primitive groups with time. Adapted from Romer (1945) and Young (1950).

lengths. However, no single individual can have all widths or all lengths of eye stripe. Instead, there are individuals with long, wide stripes, short, wide stripes, long, narrow stripes, and short, narrow stripes.

A *species* may consist of one population, but it is usually composed of several populations which are more or less independent, but do have some *gene flow* between them. That is, some members of neighboring populations do breed, so that these populations also have genes in common, though the species gene pool is less restricted in scope than is the population gene pool. Within the species, gene flow may be restricted enough between some populations to allow them to differ recognizably from others. In such cases, these are called *subspecies.* In humans the four races, Caucasoid, Negroid, Mongoloid, and Australoid, could be biologically classified as recognizable subspecies. Each has its own characteristics and, until recently, had its own geographical location. With increased gene flow between these races, the result in time will probably be a breakdown of race distinctions.

Evolution would probably not progress very far, however, if it depended solely on differing assortments of genes that are already present. Somehow new building blocks must be found, and these are produced by *mutations.* The nature of a mutation is only partially understood. Presumably, it is a structural change in a gene or even a rearrangement of genes on a chromosome which causes that gene to have a different effect than formerly.

Most mutations are small changes. Drastic changes are rarely tolerated in nature, and in the great majority of cases of large changes due to mutation, the result is early death. Mutations are usually deleterious in effect, since mutations are purely random changes, not dictated by the environment or the needs of the organism. Purely random changes do not usually benefit an organism which has evolved over a period of thousands of years in response to its environment. But, of course, beneficial mutations do occur occasionally.

Mutations are rather common. Any one gene may mutate once in several thousand individuals. Evolution is the process by which the fate of these rather common, mostly small, sometimes beneficial mutations is determined. The assortment of genes also plays an important role since certain assortments of genes are more or less beneficial than others. The environment determines the fate of genes in evolution. Every gene or combination of genes can be assigned a *selective value* in its environment. If the gene is beneficial, the selective value is plus; if deleterious, the value is minus; if it has no effect, the value is zero. The environment determines this value since a gene, and an animal possessing genes, does not exist in a vacuum but in a definite place at a definite time. What may be beneficial in one place may not be so beneficial in another. By the process of *natural selection,* the beneficial genes are selected *for* and the deleterious ones selected *against.* Since the genetic change is not usually drastic, neither is the selection drastic. It usually expresses itself in a differential breeding rate between the individuals possessing beneficial and deleterious genes. Those individuals possessing beneficial genes find adjustment to their environment easier and produce on an average more offspring than those possessing deleterious genes. This results in time in a marked shift in the whole population toward the beneficial change within an environment which is presumed to be stable. Environmental change usually results in a change in direction of evolution.

Let us return to the butterfly fish population on the isolated reef which was previously mentioned. Suppose that these fish were at one time plainly colored, small yellow fish without a vertical stripe through the large black eye. Suppose that one individual was the result of a mutation which caused a narrow stripe to appear through its eye. This stripe would be an advantage in camouflaging the otherwise very noticeable eye (*Chapter 9*), and the gene controlling the stripe could be said to have a plus selective value. It would aid this fish to avoid its predators a little better, give it a little more time to eat, and allow it a slightly longer life in which it could produce more offspring, some or most of which would also have this camouflaging eye stripe. Eventually, stripeless individuals would be rare or lacking. More mutations might also occur to strengthen this *trend* toward a stripe through the eye in butterfly fishes. Such a trend is, in fact, very evident in these fishes.

But evolution cannot be concerned merely with the change within one population. Somehow there must arise a situation whereby two types are produced from one, a splitting by which new species, families, and higher categories may arise out of the old. This can only occur if somehow the population is broken into two parts which cannot interbreed with one another. Suppose one segment of the butterfly fish population was swept away or wandered away to another distant reef. There would now be two populations on two different reefs. These populations would have slightly different mutations, and the reefs would represent slightly different environments. The results of the evolution in these populations would thus be different, and, given time, two new species would evolve which, even though rejoined, might have become so different that breeding would not occur between them. With expansion of this process of splitting, new families, orders, and higher groups may come into being. It is not too difficult to imagine how, by this process, certain fishes in shallow waters became amphibians adapted to spend part of their lives on land by selection in favor of supporting limbs, how certain amphibians became reptiles adapted to spend all their lives on land by selection in favor of an impervious dry skin, how certain reptiles became mammals adapted for active life by selection in favor of warm-bloodedness, and how certain apes became men adapted for contemplative life by selection in favor of high-mindedness. In each case, some of the descendants of the groups which gave rise to higher categories remained behind, so we see that evolution is a process that creates new forms and builds on itself. The nineteenth-century biologist Thomas Huxley likened evolution in filling the available living space on earth to the filling of a barrel. First, the barrel may be filled with apples. Then pebbles may be put into the spaces between the apples. Sand fills the spaces between the pebbles and finally water may be poured in to fill the barrel. Simpson (1949) adds that the barrel itself expands as the new forms of life create new ways of life by their very presence. For instance, without birds, there would be no bird lice, without insects no insect-pollinated flowers, and without whales, no whale barnacles.

Evolution is studied from three aspects chiefly. First, the history of evolution is given in fossil form—paleontology. Second, the mechanics of evolution are revealed by genetics. Third, the all-important environmental effect is examined by ecology, commonly known under the name of natural history. We have briefly explained the first two. This book mainly concerns ecology, and three

phenomena observed by ecologists and paleoecologists studying evolution are so instructive that they must be mentioned.

First, there is the phenomenon of *convergence.* Unrelated animals living in similar environments or having similar habits are under similar environmental stress and frequently come to look alike. Porpoises, for instance, are adapted for a swift-moving, fish-eating existence on the open sea. Before mammals became dominant, when the reptiles reigned, a group of reptiles called "ichthyosaurs" with porpoiselike habits were remarkably like porpoises in body form. The whales and whale sharks are remarkably alike and have similar habits. There are many eel-shaped fishes all adapted for secretive predacious lives, yet derived from widely different groups of fishes. These are all examples of convergence of body form in response to similar habits and habitat.

The second phenomenon is *parallelism,* which differs from convergence but little. Again it concerns evolution of animals in response to similar conditions, but, unlike convergence, the groups were not widely divergent to start with and have merely followed parallel courses in evolution. The demoiselles and the butterfly fishes are very similar in habits, size, and form and were derived from fairly closely related suborders of fishes. There are several predacious species of bottom-dwelling fishes such as toadfish, scorpion fish, stargazers, etc., which have developed from closely related stock.

The third is *adaptive radiation.* All groups of animals will tend to evolve in all ways that are open to them within the limits of their own anatomies. Thus the reptiles and mammals have both had swimming, running, flying species. The fishes have radiated into almost every conceivable niche from the surface to the deep sea, from plankton and plant-eaters to voracious carnivores, and from life on rocks and reefs to sandy beaches. Even smaller groups of fishes show their own radiation patterns. One has only to examine the varied mackerel-like fishes—swift predators, plankton feeders, eellike forms, etc.—to see radiation at work.

Evolution is a dynamic, continuing process. It is going on today even in the human species. Rarely does it come to a halt in any group. When such a halt occurs, the result is usually extinction—especially when environmental change occurs—but occasionally a seemingly changeless "living fossil" is left behind: the oyster, the horseshoe crab, the sturgeon, *Lingula.* Evolution is a peculiar combination of the randomness of mutation and the orientation of natural selection. It is natural selection imposed by the environment that keeps species within bounds. Without it, deleterious genes could accumulate, and the result would almost certainly be genetic pandemonium, which could only result in environmental maladjustment and extinction.

Evolution is highly opportunistic. New situations are quickly met by organisms that seize new opportunities, but such meeting is largely due to the chance that the animals are present to meet these opportunities and the chance that mutations of plus selective value occur. Islands or isolated coral reefs, for instance, have notably depauperate faunas simply because many groups of animals have not found their way there.

Evolution seems slow to humans who measure time in minutes, hours, and years. Geologic time is not so reckoned. To the human eye, the world is a static place, but this eye sees only one frame of a moving picture. We should

not forget that the human life is too short to see evolution in action and that the human animal has been on earth only one thousandth of the time that life has existed here. The age we live in is, in fact, an extraordinarily dramatic one typified by the harsh climatic conditions of an ice age, by fluctuating currents and water levels of the sea, and by the geologic upheaval of whole great mountain ranges such as the Pacific Coast range. But our lives are too short for us to notice most of these changes.

Evolution has no goal, but it does have method and a reason. The necessity of life to adapt to an ever-changing and complex environment is its reason. The sensitive man will contemplate and study these things as he swims among the wonders of the sea that lie about him.

NAMES

It is of utmost practical necessity that names be given to the species of marine life about us. For common everyday purposes, common everyday names are used. These are sometimes adequate. Mostly they are not. When you eat a sardine, do you spread a small herring or a pilchard or a Spanish sardine on your bread? These are three different fishes, all-called "sardine." Different languages have different words for the same fish; for example, "ronco" (Spanish) and "grunt." "Langouste" (French), "crayfish," and "spiny lobster" are all names referring to the same animal. Examples are virtually endless of the confusion, multiplicity, and overlap of common names that are given to marine animals and plants.

Common names are given by just about every method imaginable. The margate fish was named for the sailors from the English port of Margate. The yellow grunt was named for its color. The pompano was named for its shape. Gill's mojarra was named after a man. No one knows how or why the ridley turtle got its name.

Obviously, some way had to be found out of this imbroglio of terms. In the mid-eighteenth century, a Swedish scientist named Linnaeus founded the system of scientific nomenclature which we use today. There is no need to be confounded or overimpressed with scientific names. They are only names, after all, which may be a little foreign to most of us but which offer us some stability in the confusion of names, especially when we are not familiar with the local terminology.

CLASSIFICATION

Linnaeus's system for naming animals is built around binomial nomenclature. That is, every species is given two names, a first, capitalized, generic name, and a second, uncapitalized, species name. The genus of the spotted moray is *Gymnothorax;* the species is *moringa.* The complete name is *Gymnothorax moringa.* The subspecies name, if any, adds a third name.

The Linnaean system was originated in a time before the acceptance of the validity of evolution. Linnaeus himself was a special creationist. Nowadays his system has been adapted into an evolutionary scheme and supposedly reflects the tree of evolution as it is revealed to us by the study of fossils. But since the

fossil record is far from complete and since the interpretation of it is subject to human frailty and differences of opinion, there are several systems of classification which involve duplications and overlaps of the same type that occur in common names. Are the triggerfishes, trunkfishes, and puffers three separate suborders, or are they three parts of one suborder? Opinions differ and names are invented to express the differences. Luckily, there is little difference of opinion regarding families, and they can be given the strongest reliance. This is due to the fact that the families of animals and plants form fairly distinct groups. For some reason, the transitional species that unite families are short-lived and usually do not stay around long enough to give scientists a chance to examine them or their fossil remains. This is probably because families share the characteristics of an adaptive type which is established quickly in evolution, so quickly that there are few intermediates. Basically, the classificatory system of living things is built as follows:

Kingdom: only two in number—animal and plant.
Phylum: the largest subdivision, e.g., Chordata, including protovertebrates and vertebrates.
Class: a major phylum subdivision, e.g., Osteichthyes, including all bony fishes.
Order: a prominent assemblage of families, e.g., Apodes, including all true eels.
Family: the basic "adaptive type" grouping, e.g., Muraenidae, including all moray eels.
Genus: a distinct morphological type; e.g., *Gymnothorax,* including an assemblage of very similar species.
Species: the unit of interbreeding individuals, e.g., *Gymnothorax moringa,* the spotted moray eel.

It will be noticed that there are seven subdivisions in this system. As we progress down from kingdom to species, the evolutionary relationship between comparable groups becomes closer and closer (*fig. 17*). Most often, however, seven subdivisions are not enough to express the numerous branchings of the evolutionary tree, so the prefixes "sub," "super," or "infra" may be added to the seven primary divisions or new categories such as *cohort* or *tribe* may be added. The basic system between class and genus may thus be expanded:

Cohort
Superorder
Order
Suborder
Infraorder
Superfamily
Family
Subfamily
Tribe

Just as evolution is complex and increases in complexity as we learn more about it, so the classificatory system increases in complexity in an attempt to reflect evolutionary patterns. There is some effort to stabilize this system. This

takes the form of rules set up by an international committee on nomenclature (Schenk and McMasters, 1948). Family names end in "idae," subfamilies in "inae"; modern taxonomists end orders in "iformes," suborders in "oidei," and superfamilies in "oidea."

In the following pages an attempt is made to use the simplest classification possible. Classification is no idle business. The whole point of it is to simplify, and the underwater swimmer will find it to his benefit to try to think in terms of a classificatory system in which each species has its position in a family which, in turn, has its place in an evolutionary system. An effort should be made to have in mind a hypothetical family image which gives the species of the family their major characteristics. This book is built around the convenience of having such family images, and a "type" system has been used here (Introduction).

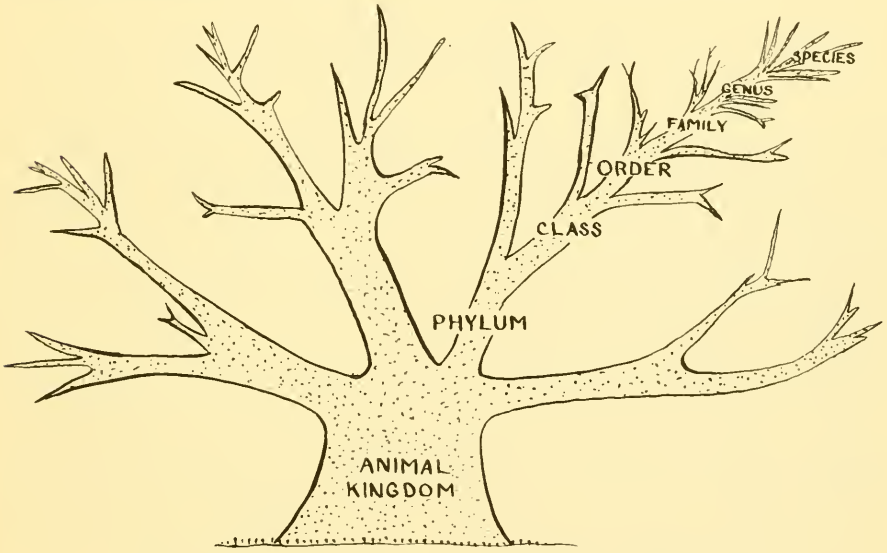


Fig. 17. The relationship between the evolutionary tree and classification.

SECTION TWO

Flora and Lower Fauna

CHAPTER 6

PLANTS OF THE SEA

With the notable exception of eelgrass, *Zostera,* and turtle grass, *Thalassia,* flowering plants, most of the marine flora is made up of algae. The word "algae" is a catchall for several very distinct groups. Their variation in size is immense, ranging from microscopic to 200 feet in length. The variation in color is no less striking, ranging from blue-greens and greens to reds, violets, and browns. All of them, however, possess the pigment chlorophyll, which is without doubt the single most important plant compound known. Without it, plants would not be able to utilize the sun's light energy to manufacture carbohydrates (and, by addition of minerals, proteins) from carbon dioxide and water. This process is known as "photosynthesis" and is responsible for all life on earth since it is at the very base of the food chain. Chlorophyll absorbs light at the blue and red ends of the spectrum and reflects green, the color it appears to our eyes. The blue and especially the red light that is absorbed provides the energy used in photosynthesis. Since sea water absorbs light differentially, eliminating the reds and then the yellows until, at over 65 feet, very little but green and blue are left, the quality of light available at various depths influences the distribution of the variously colored algae. This subject will be considered as each group is discussed.

The smallest algae as well as the most important in the sea's economy are the planktonic ones, which are single-celled, usually enclosed in a skeleton, and which float or swim near the ocean's surface in immense numbers. There they form the grass of the sea, a vast and nourishing pastureland. The larger algae are mostly confined to shore, shoal, rocky, and reef waters, where they are anchored to rocks, shells, wharves, or even other algae (in which case they are said to be "epiphytes"—*epi,* meaning "on," *phyte,* meaning "plant." These types are most dense on shores sheltered from beating surf and, for that reason, Long Island Sound and Monterey Bay have particularly dense and varied floras. The large algae are easily separated from all other plants by their lack of true roots, stems, or leaves, although they have basal holdfasts which look superficially like roots and an upright, usually branched structure that looks like a stem and bears flat, leaflike extensions.

The one place where no photosynthetic plant can exist, of course, is in very dim light or darkness. Because photosynthesis is impossible in such places, one would not expect to find photosynthetic algae below a depth of about 200 feet. Algae become rare below 100 feet. These figures vary according to the nature of the water.

One group of single-celled animals (Protozoa) is commonly referred to as being more closely related to plants than to animals. This is the zoologists' Flagellata or Mastigophora or the botanists' Euglenophyta. Flagellates are considered by many scientists to be a perfect link between animals and plants since they achieve mobility by means of flagella as do many animals, yet are able to manufacture food by photosynthesis as are most plants. Obviously, according to evolutionary theory, before there were true animals or plants, there must have been some group that gave rise to both and thus possessed the potential attributes of both. Such a group is Flagellata, a group which is considered in the chapter on invertebrates simply because its members look and act more like animals than plants. Flagellates, like small one-celled true plants, are planktonic and form a basic food of the sea. Many algae have sexual stages, notably the male sex cells, that closely resemble protozoan cells.

Bacteria are very minute and simple plants. They are not true algae. Their very simple order of construction sets them aside from all other plants. They are well known as the causal agents of many diseases and are probably the most common of all living things. They will not be included here, but it must be remembered that they form a basic food for many of the small one-celled animals. Some of them are unique among living things in their ability to use inorganic compounds (nitrates, nitrites, and sulphur compounds) as a source of energy. This method involves no photosynthetic process and indicates the primitive nature of bacteria (deep sea food chains, Chapter 2).

Many plants of the sea, like garden plants, are known only by their scientific names. Most of the genera described and figured here have several species widely distributed on both coasts.

DIATOMS: Phylum Chrysophyta—*Figure 18*

Diatoms are microscopic one-celled algae that live in immense numbers near the surface of the sea, being the most common planktonic plant. They are enclosed in a siliceous shell of great variation and beauty. The shells may be

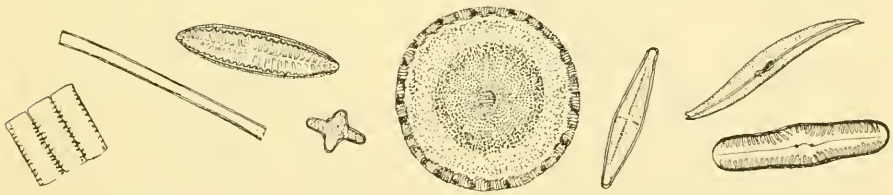


Fig. 18. Diatoms. The diatoms are shown much enlarged, the circular one being only about one-fiftieth of an inch in diameter natural size. Drawn from microphotographs by the authors.

rectangular, round, ovoid, or oddly club-shaped but are almost always marked by regular lines or pores, which may be, in some instances, so fine and regular that they are used to test the resolving power of the finest microscopes. The accumulated shells are deposited as diatomaceous earth, which has a number of extremely important commercial uses, such as insulating furnaces, preventing afterglow in matches, filtering oil and beer, acting as an abrasive in silver and car polishes, purifying water, and clarifying antibiotics. The accessory pigment fucoxanthin is present as in the brown algae, and its role will be discussed under that group.

BLUE-GREEN ALGAE: Phylum Cyanophyta

The dark, blue-green color of most of these most primitive algae is a combination of the blue of phycocyanin and the green of chlorophyll. Some of them also have a red pigment. *Trichodesmium* is one of these algae and is sometimes present in such quantities that it gives the sea a reddish color. The Red Sea is said to have been named because of the occasional presence of this alga. Blue-green algae are small, inconspicuous, slimy algae found most typically in fresh-water ponds as scum and in the sea adhering to mud, rocks, or wharves. Their small size frequently requires microscopic examination for identification. Mermaid's hair is found adhering to rocks, mud, and wharves of both coasts. Like other blue-green algae, it forms a dark, fuzzy, somewhat slimy mat on the surface to which it is attached.

The pigment phycocyanin absorbs orange and red very efficiently and passes on the energy so acquired to chlorophyll, which uses it for photosynthesis. Almost no blue light is absorbed by these algae so they must live in very shallow water, although Marshall (1954) reports the presence of blue-green algae in the deep sea. They must live on decaying organic matter, somewhat like fungi, there.

GREEN ALGAE: Phylum Chlorophyta—*Figure 19*

The vivid green color of these plants is due to chlorophyll, which identifies them. They are very numerous and are the most diversified and complex of algal groups, having 5,700 species the world over. They are especially familiar as pond scum, on rocks in streams, or on the bark of trees (*Protococcus*). In the sea, the green algae are mostly small and of temperate to tropical distribution, being more varied to the south. They are not as conspicuous as red and brown algae. The marine green algae vary from flagellated, planktonic, microscopic, colonial, or single-celled forms, *Dunaliella,* to the small, branched, filamentous forms found attached to rocks in the intertidal zone, *Cladophora,* and the showy, large sea lettuce, *Ulva,* which is usually found attached to rocks, other algae, or wharves just below the low tide mark. Sea lettuce reaches 3 to 4 feet in length and has a very wide distribution from the subarctic to the subtropics. It is fragile and is frequently broken by wave action and thrown up on beaches. *Enteromorpha,* sometimes called "grass," is a genus of many species, most of which are very small. Some, however, reach 2 feet or more in length. The plant is either single or branched, and the blades are usually round and tubular and are always hollow. Most of the species are of the temperate zone. Sea moss, *Bryopsis,* is a lovely, plumose plant which grows to 8 inches high.

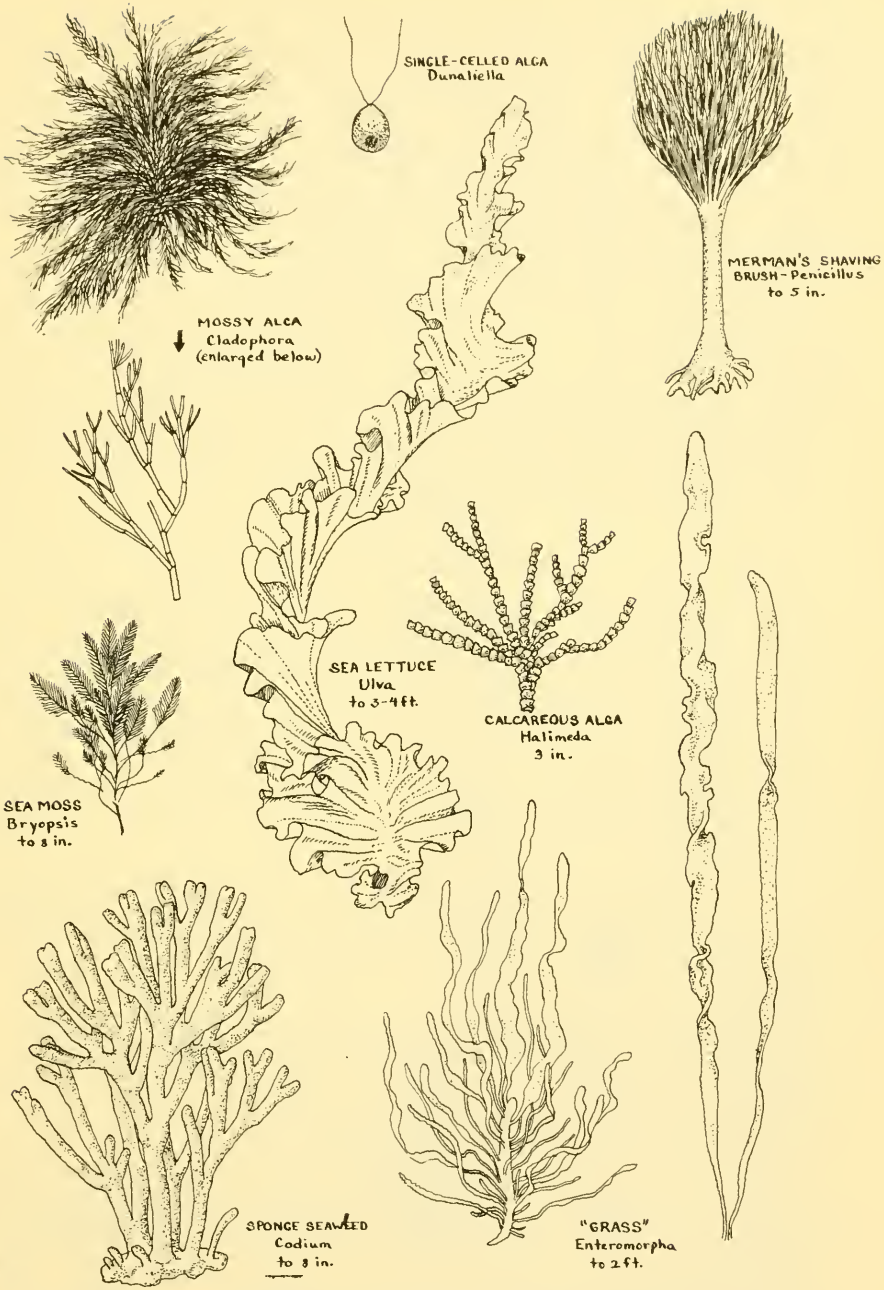


Fig. 19. Green algae. Adapted from Smith (1944) and Taylor (1937).

It may grow in sand, or mud, in tidepools, or on wharves and rocks. It is temperate and tropical in distribution. The sponge seaweed, *Codium,* has a spongy texture and is branching. It is very common in the warm waters of both coasts. It grows to a height of about 8 inches. A few green algae are calcified as are many red algae. *Halimeda* is a tropical reef-building calcareous alga. One of the oddest of green algae is the tropical merman's shaving brush, *Penicillus* (*fig. 43*). It grows to 5 inches high, and the name perfectly describes its shape.

The green algae are probably the ancestors of all later plants. They show strong similarity to higher plants in their pigment chlorophyll, which is carried in typical bodies in the plant cells called "chloroplasts." Chlorophyll is green, so it absorbs all colors of the spectrum except green, which it reflects. Therefore, the chief light rays used in photosynthesis are of the red and blue ends of the spectrum. Because there is very little red left in water below 15 to 20 feet, the green algae cannot photosynthesize efficiently there and are rarely found in this greenish water. Surprisingly enough, some green algae live deeper than any other photosynthetic plants. Some are found at depths of 200 feet where they use the dim blue light that is available.

BROWN ALGAE: Phylum Phaeophyta—*Figures 20 and 21*

This is an almost exclusively marine group of over a thousand species and includes the largest and most conspicuous of all algae, the kelps. The color is brown to olivaceous and is caused by the presence of fucoxanthin, an accessory pigment which increases absorption of green light. Fucoxanthin passes the energy it absorbs on to chlorophyll for utilization. Chlorophyll itself absorbs reds and blues for photosynthesis. Thus, brown algae are the most successful utilizers among algae of a wide range of the colors of the spectrum and are, therefore, the most conspicuous and most varied algae of the sea, both in form and habitat.

The brown algae are typical of rocky shores from the tidal zone to depths of 50 or 100 feet or more. The deeper ones are long, however, and are able to reach up into shallower waters for light. The temperate to arctic zones see the greatest variety and abundance of them, though they are present in tropical seas also.

There is a great variety of form among these algae. Most of the following are of temperate to arctic distribution and are found on both coasts. *Ectocarpus* grows to 12 inches and is filamentous and branched. It frequently grows on other algae, that is, is an epiphyte. *Fucus,* rockweed, is very common on rocky shores in the tidal zone. This is the alga that makes whole shores look brown. It has little buoying bladders along the stem, which, when dry, make a popping noise as they are burst underfoot. Rockweed is not found in tropical waters but is the most common seaweed north of Cape Hatteras and central California. *Ascophyllum* is like rockweed but reaches tropical waters. It grows in the same places as rockweed, but there is no midrib on its stem as there is on *Fucus. Desmarestia* is a large genus of bushy, branched algae which grow on rocks and is abundant only in the warmer months. The branching identifies them, being pinnate, that is, branches extend from the main stem on both sides of the central stem, which is not itself branched. Most *Desmarestia* species are small, but some reach 6 feet in length. Sargasso weed, *Sargassum,* was discovered by

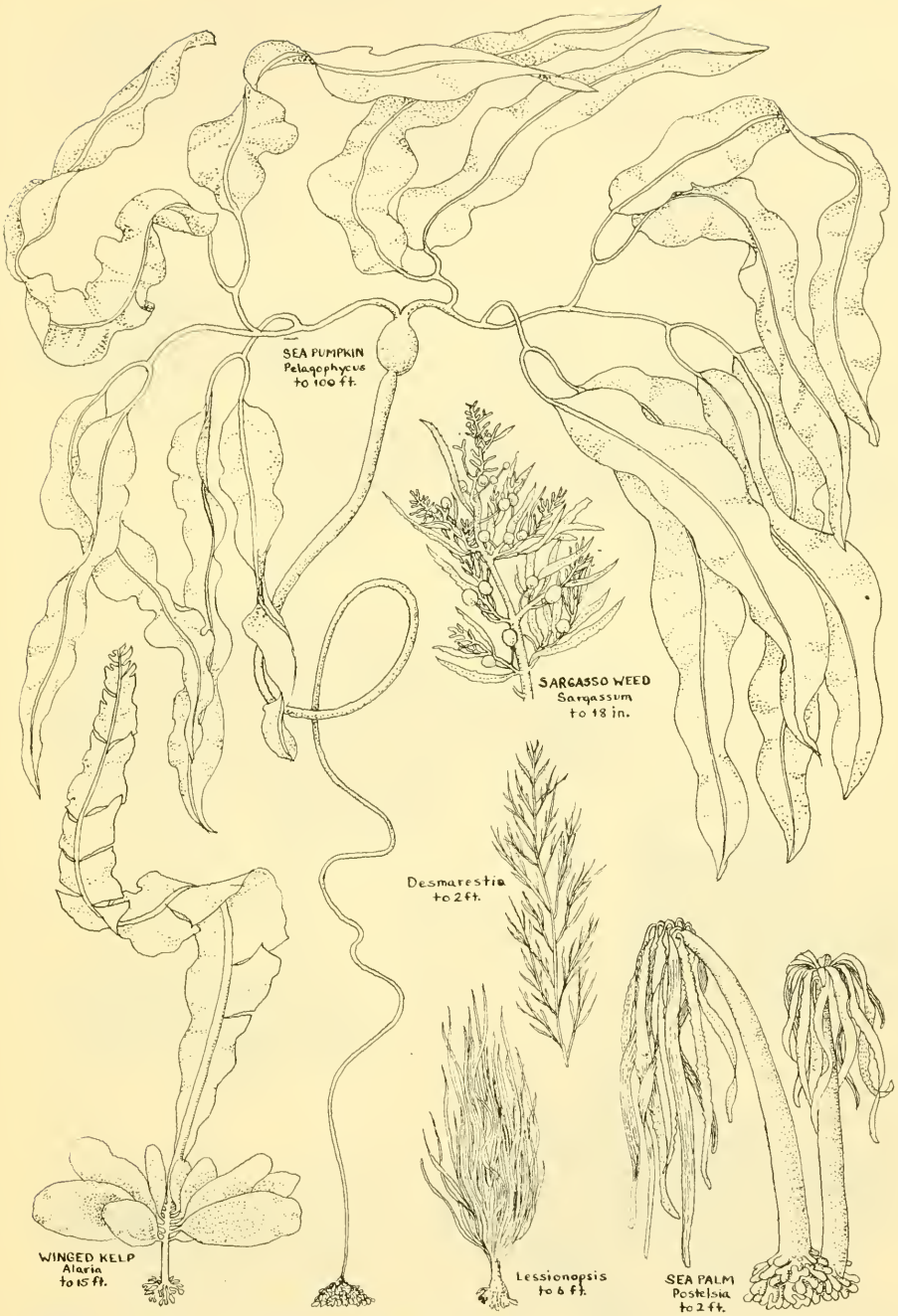


Fig. 20. Brown algae—plate 1. Adapted from Smith (1944) and Taylor (1937).

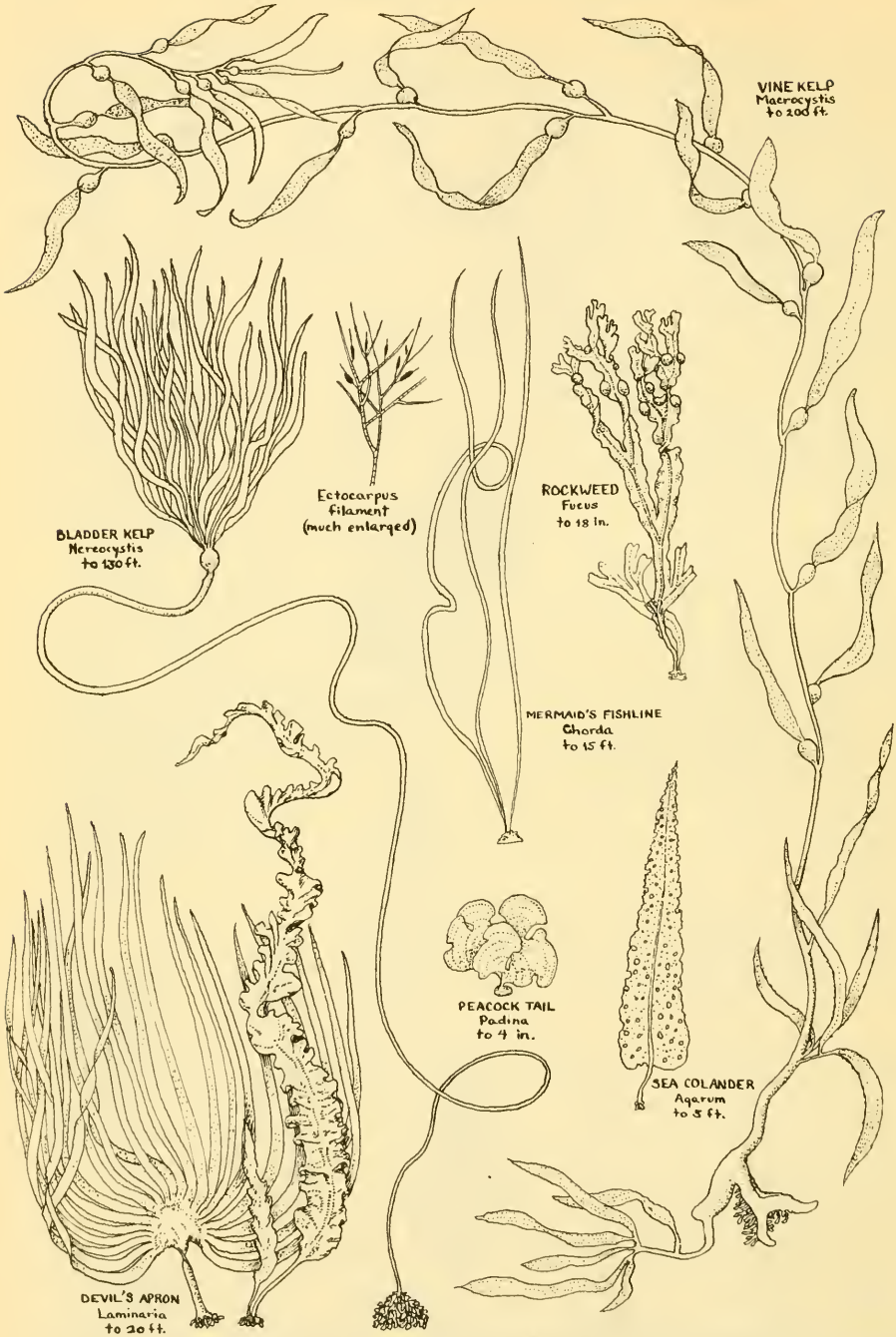
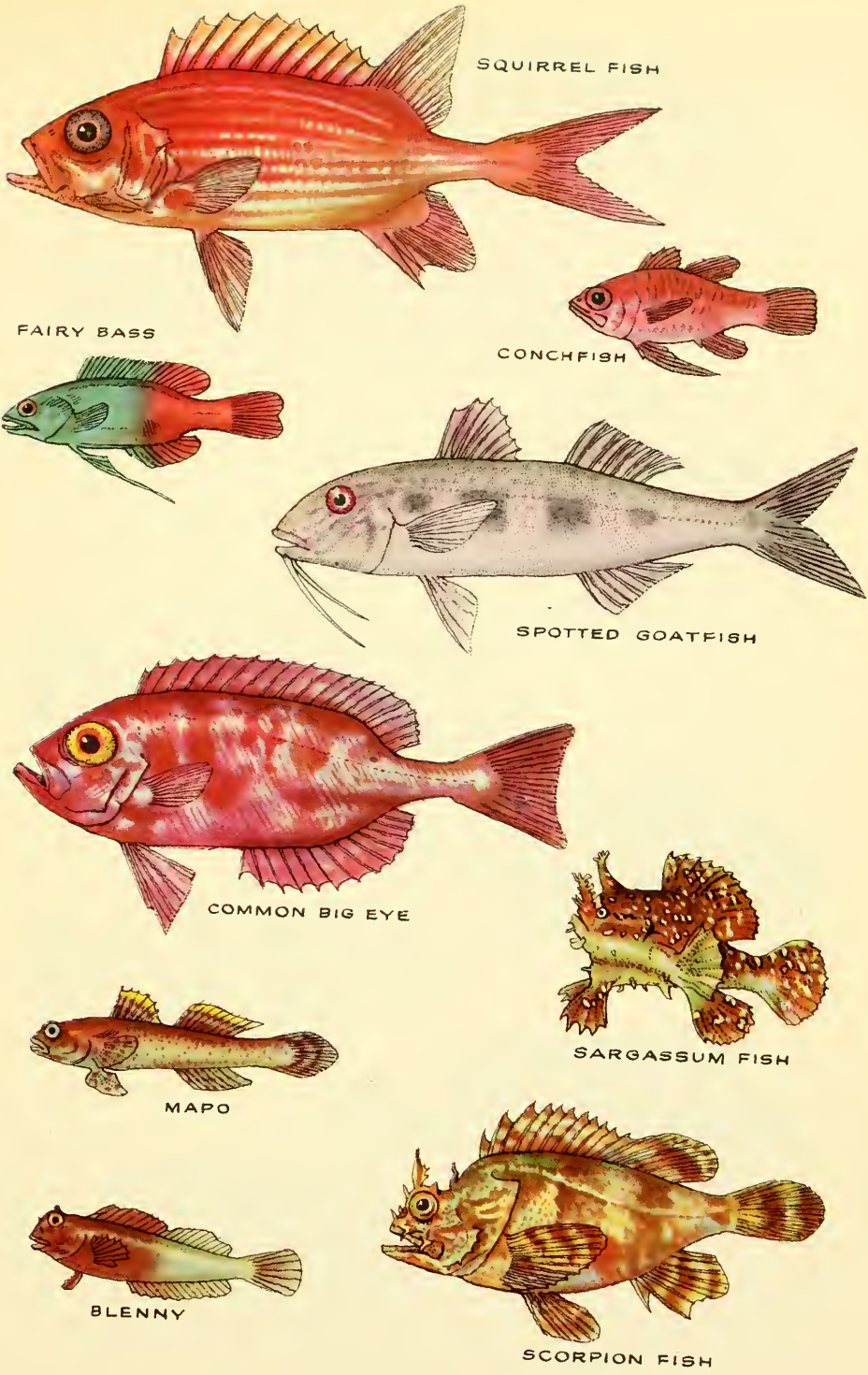
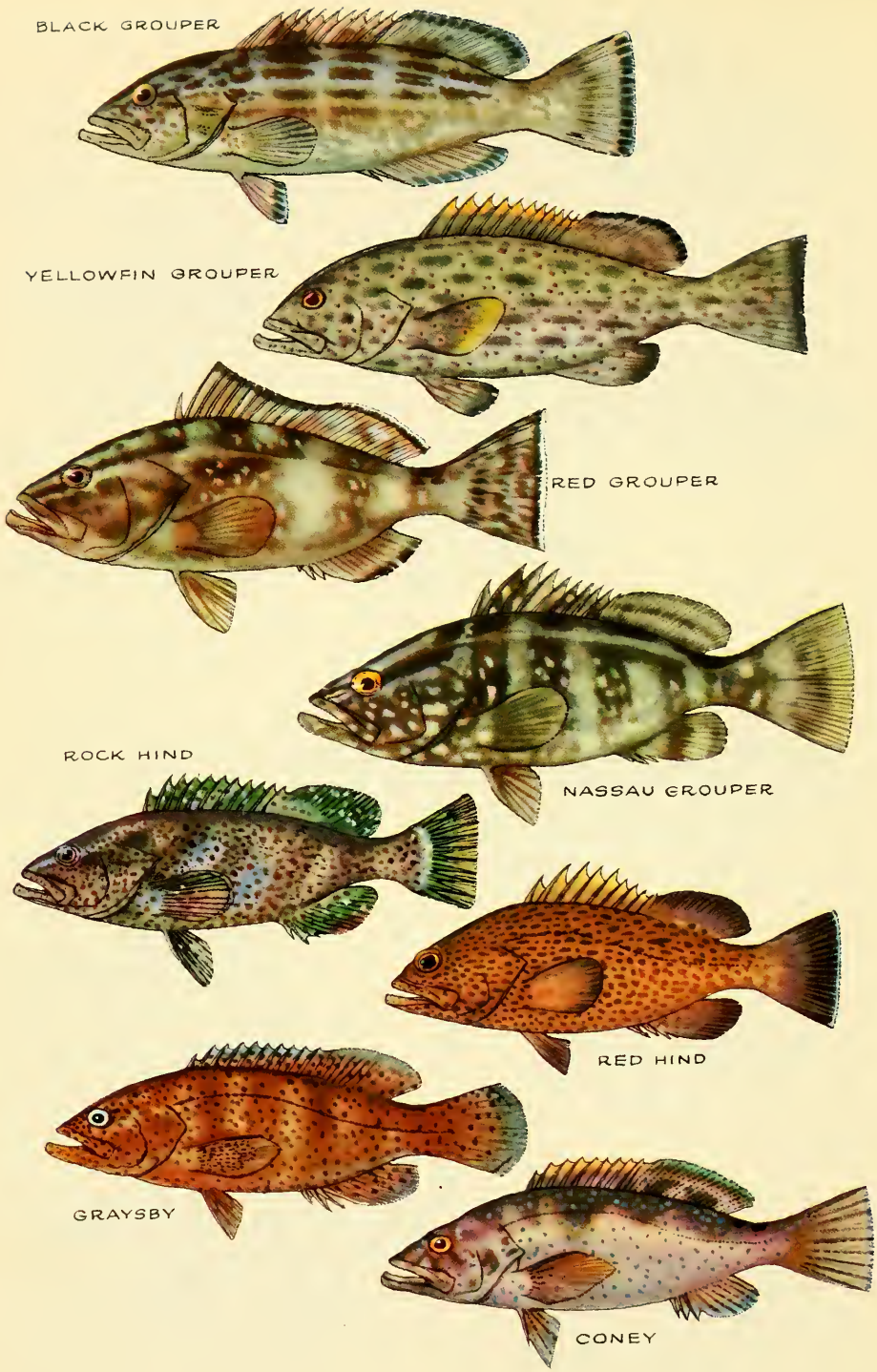


Fig. 21. Brown algae—plate 2. Adapted from Smith (1944) and Taylor (1937).



COLOR PLATE 3



COLOR PLATE 4

Columbus in 1492. It lives and breeds on shores in the Caribbean, but breaks off during storms, becomes pelagic, floating in clumps, and is carried to the Sargasso Sea between the Bahamas and Bermuda by the Gulf Stream where it propagates by fragmentation. It forms the basis of a fauna all its own (Chapter 1). The mermaid's fishline, *Chorda,* is well named for its ropelike, unbranched strands, which reach 15 feet in length. Beds of this alga are sometimes very extensive especially on the East Coast. *Chorda* is an annual, growing each spring.

The various kelps are the largest of algae and among the largest of all plants. The immense beds of kelp are especially well known on the West Coast. They can be dangerous to swim in, the long, very tough tendrils easily snagging the swimmer or his equipment. They harbor a great number of fishes as well as the famous and rare sea otter. Some kelps, however, are small and live in tidal zones. The typical kelps or devil's aprons belong to the genus *Laminaria.* They reach 15 to 20 feet in length but are usually seen much smaller. The wide, flat blades are typical. In the common species, these blades are single, but other species may have several blades rising out of a single stipe (stem). Other kelps are the bladder kelp, *Nereocystis,* which is found in waters up to 100 feet deep and grows best on shoals or rocks near active waves or currents; the sea colander, *Agarum,* a seedy-looking plant with a perforated blade, which grows up to 5 feet long in the north temperate Atlantic; the sea pumpkin, *Pelagophycus,* which is a large kelp found from Santa Barbara to Baja California; the vine kelp, *Macrocystis,* which is the longest of all algae, with a length of up to 200 feet.

Lessionopsis is a very bushy brown alga which reaches 6 feet in length. It grows on rocks exposed to surf and is found only on the West Coast from Alaska to Carmel, California. *Alaria* is large, sometimes up to 15 feet or more in length. It has a prominent midrib and a group of small blades near the base of the stipe. It is found on both coasts, mainly in colder waters. The sea palm, *Postelsia,* is a very odd alga which grows on the West Coast in shallow waters where it is exposed to the full force of the waves. *Padina,* the peacock tail, is a leathery, funguslike form found in the tropics. It grows to a few inches in height.

Some brown algae are of considerable economic importance. Gelatin and the filler used in cheap ice creams come from them. They are widely used as food, especially in the Orient.

RED ALGAE: Phylum Rhodophyta—*Figure 22*

It is often stated that red algae are adapted better than other algae for life in deep waters. It would be perhaps better to substitute "intermediate" for "deep," for these algae are able to utilize not the light of shortest wave length, the blues, which most deeply penetrates the water, but rather the light of intermediate wave lengths, the greens. Red algae possess the accessory pigment phycoerythrin, which imparts a red to deep purplish color to the plant. Sometimes the color may be orange or olivaceous. Phycoerythrin absorbs the light which is almost exactly complementary to that absorbed by green algae. The greens of the spectrum are most efficiently used by red algae, while reds and blues are not of much use. Therefore, red algae tend to replace green algae in water over a few feet deep and are found in waters to 100 feet or more in depth. They are most common, and most efficiently photosynthetic, at 15 to 50 feet, the depth where green light predominates and red light is weak.

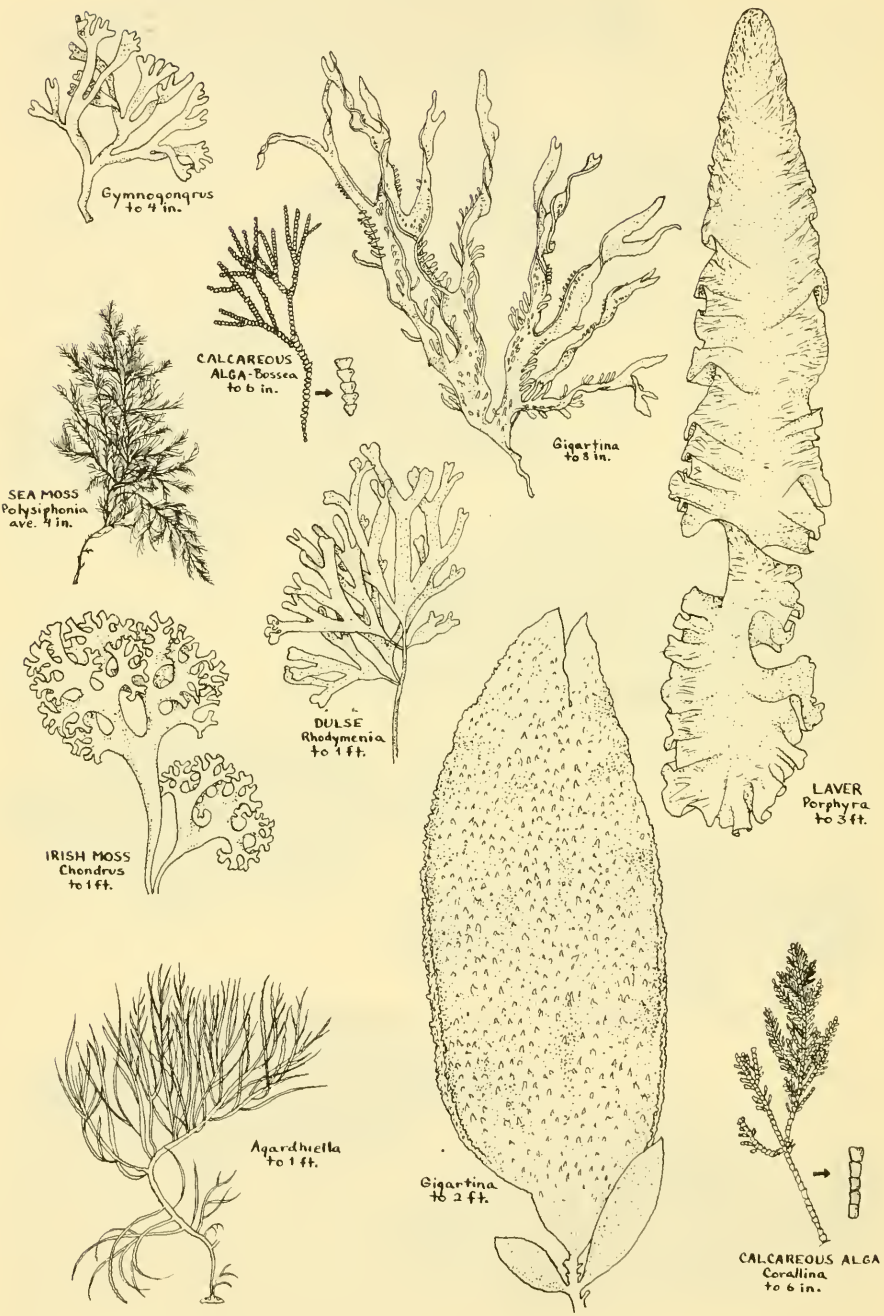


Fig. 22. Red algae. Adapted from Smith (1944) and Taylor (1937).

Most red algae are small and filamentous or branched. For that reason they are frequently called "sea mosses." Many genera are much alike and frequently hard to identify. Red algae are most common in temperate to tropical seas. There are 2,500 species the world over.

Laver, *Porphyra*, looks like sea lettuce and is frequently epiphytic—found growing on other plants. Like sea lettuce, it is fragile and washes up on beaches or into shallow water. It is found from the subarctic to the tropics and is orange or red to purple in color. It reaches 3 feet in length. *Gymnogongrus* is a beautiful and striking dark purple alga which looks like a small rockweed. It frequently grows among tropical coral but is also found in the temperate zone. It has a firm or even horny texture. *Gigartina* has a wide range of habitats from quiet sandy shores to rugged rocks where it must withstand the pounding of a heavy surf. It may be olive to purple or rose-red in color, and the surface is roughened by little outgrowths. The texture is leathery, and the plant may be branched, single, or spatulate in shape. *Polysiphonia* is very mossy in texture and finely branched. It is commonly only a couple of inches in length but may reach 3 feet. The color is a dark purple to brown or black, or even olivaceous. The many species are found from the arctic to the tropics of both coasts, and they grow anchored to rock, wharves, or other plants from the tidal zone to moderately deep water. The Irish moss, *Chondrus*, is very common, growing on rocks in shallow water. The various species are quite variable, but all are bushy and not over a foot tall, most being only a few inches. The color is a rose- to purple-red, or even with a green tinge, and the distribution temperate. It is a source of industrial chemicals. The dulse, *Rhodymenia*, gets into fairly deep water and is also found in the tidal zone. It looks like rockweed or *Gymnogongrus* in its branching and is a pretty, bright purplish red in color. It is of temperate distribution, keeping to deeper waters to the south of its range. Very often species of this genus have little bladelets at the tips of the main blades. Several species reach a length of a foot, but most are smaller. *Agardhiella* is a treelike, small, branched red alga which is very common on temperate coasts. It is frequently heavily burdened with crustaceans and other animals that live in its branches.

Several red algae deposit calcium carbonate or lime around themselves. Some of these aid in the building of reefs. *Corallina* ranges from the tropical to the temperate zones of both coasts. It is a dull purple or red in color and reaches a height of 6 inches. *Bossea* is a West Coast coralline alga, which grows on rocks in shallow water. It reaches a little over 6 inches but is mostly much smaller.

SEED PLANTS: Phylum Tracheophyta

The eelgrass, *Zostera*, and turtle grass, *Thalassia* (*fig. 43*), and their close relatives are alone among the truly marine seed plants. They live in sandy, or muddy, quiet shallow waters. The leaves are slender and reach up to 4 feet in length. These plants send out long runners to propagate and bear small flowers and seeds. Many animals such as sea horses and green turtles depend upon these grasses for homes or food. It is unfortunate that because of pollution and parasitic infestation eelgrass has disappeared from much of its former territory. These plants range from the arctic to the tropics of both coasts.

CHAPTER 7

THE INVERTEBRATE LEGIONS

The diverse series of phyla that compose the invertebrates is so complex that the subject will be treated here on the level of the largest groups—classes and orders. This task in itself can be more complex than it would first appear to be, since 95 per cent of all of the species of animals are invertebrates.

So huge is the invertebrate group, that no living man can say that he thoroughly comprehends even a majority of their vast array. Thus, the study of them is divided into a great number of subsciences—entomology for insects, protozoology for protozoans, conchology for molluscs, and so on. Nevertheless, comprehension of the types of invertebrates on at least a phylum and class level is possible, and we believe that such a treatment is vital in understanding the life of the sea. (More thorough treatments are available as listed in the Bibliography.)

The study of invertebrates can be a fascinating thing. Because their ways of life are so far removed from the realm of man, one cannot help but be constantly struck by a sense of the bizarre. Most invertebrates possess very limited brain power and do not vary their habits as much as do vertebrates, but within the limited behavioral pattern of each lie constant surprises. The colors and the beauty of form and motion of many of them are often breath-taking, and their odd habits are constant sources of wonder.

The invertebrates are united by the possession of no single characteristic, but rather by the lack of one. None of them has vertebrae or a backbone. Formerly, Aristotle separated invertebrates and vertebrates on the basis that vertebrates possessed blood and the invertebrates supposedly lacked it. His word on this matter was accepted until only 150 years ago when invertebrates were shown to possess blood, though it is frequently colorless.

In the following pages, the major habitat and ways of life of each group are given, together with brief descriptions of a few representative species.

NONCELLULAR ANIMALS: Phylum Protozoa (*first animal*)

A noncellular animal is one whose body is not divided into cells. Therefore, within the single cell of most protozoans, all the functions of digestion,

respiration, locomotion, and so on are carried out. It is true that some protozoans are colonial—several living together as a single group—but none of these has a division of labor among cells in which the cells are united into organs for special purposes.

This phylum is the most variable one in either the animal or plant kingdom. No one body plan, form, or type of symmetry typifies all protozoans. Some species, like *Amoeba*, are even able to change their form as they move about, but most species have one form that typifies them throughout their lives. Protozoans are among the largest of phyla, existing practically everywhere—in sea water at all depths, in fresh water, on land, and broadcast through air as spores. Some are parasitic, causing such diseases as amoebic dysentery, malaria, and African sleeping sickness.

Protozoans are all small. A microscope is required for seeing their details of structure, though many can be seen with the naked eye. They range in size from a few thousandths of a millimeter (1/25 of an inch is equivalent to 1 mm.) to an extreme of over ¾ of an inch for some fossil, amoebalike protozoans with skeletons. Protozoans reproduce by fission, a simple splitting of a cell in two, a method which allows them to increase their numbers rapidly when the right conditions prevail. Just when and where these conditions prevail is the key to understanding protozoans, for they are all extremely sensitive to environmental modifications. Under the proper conditions of salinity, temperature, viscosity, pressure, light, food, etc., the numbers of a certain species may become incomprehensibly immense. If these conditions change only a little, the species will often die off and produce dormant stages, such as resistant spores which will become active again only when conditions once more become adequate. But so great are the numbers of species of protozoans that almost any conditions are adequate for at least one or two species. Rarely, if ever, are any waters free of them.

Protozoan behavior never varies much within a species. Some species are light-sensitive, moving toward or away from it. All react to mechanical shock and temperature change, and most can sense food, moving toward it.

Most of the protozoans with which we shall be concerned are planktonic and occupy a vital place at the very base of the food chain, either deriving their body-building energy directly from the sun or from bacteria or other minute particles which they eat.

Flagellates: *Class Flagellata or Mastigophora—Figure 23*

This group, which forms a link between true animals and true plants (algae), occupies an extremely important place in evolution. Some of them contain chlorophyll and are photosynthetic, looking very much like some single-celled green algae (*Dunaliella, fig. 19*). Others eat food such as bacteria or decayed substances as do animals. The photosynthetic species have a light-sensitive eye and move toward light. They are extremely important in the sea as basic converters of light energy to carbohydrates.

All of the flagellates have one or several flagella, or whiplike filaments, which move the animal. Some flagellates are colonial with several cells living together as a unit, and these bear a remarkable similarity to the sponges in that there is a

subordination of the single cell to the life of the whole colony, a prerequisite for a many-celled animal.

This group forms the greatest of all linking groups in evolution. Not only does it unite animals with plants and protozoans with sponges, but the other groups of protozoans, as well as higher animals, were probably derived from flagellates.

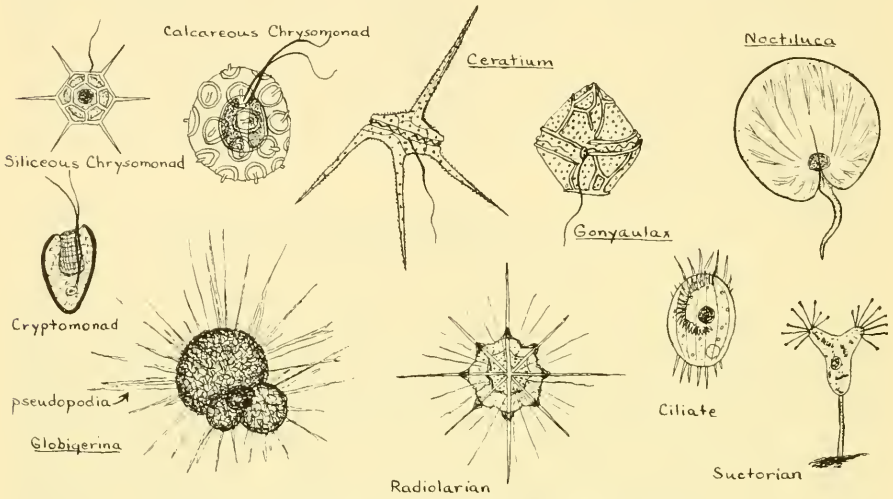


Fig. 23. Protozoans. Adapted from several authors.

The chrysomonads form a group of predominately photosynthetic planktonic flagellates. They very often have a siliceous or calcareous skeleton and almost always have two large, conspicuous yellow or brown bodies (chloroplasts) within them which contain chlorophyll.

The cryptomonads are oval-shaped and have a large gullet in which two flagella arise. Some are photosynthetic and others ingest organic matter through the gullet. None of these has a hard skeleton.

The dinoflagellates are the largest and most numerous of the marine, planktonic, photosynthetic protozoans and are of enormous importance in the economy of the sea. The body is most often encased in plates made of cellulose, and there are two flagella, one of which rests in a groove which circles the body. *Ceratium* is a common form in which long spines are developed as a flotation mechanism. The red tide organism, *Gymnodinium brevis*, occurs sporadically in tremendous numbers along the coast of the Gulf of Mexico and in other warm seas. When it appears, sea water is turned into a muddy, reddish color and syrupy consistency, causing a high mortality of marine life. If the temperature is high, it produces a vapor that is very irritating to eyes, nose, and throat. No one knows what causes sudden outbreaks of red tide. *Gonyaulax* causes similar damaging outbreaks of "red water" in Southern California. *Noctiluca* is luminescent and non-photosynthetic. It is large, to 1/25 of an inch in diameter, and when it is disturbed by a wave, a boat, or a swimmer, will emit a sudden light. The combined light of countless millions of them causes a beautiful, sparkling glow on the water's surface. The natural color of *Noctiluca* is pale pink and by day a pinkish tint may be given to the sea by them.

All of the three groups of flagellates mentioned have some species which

live in symbiotic relationship in the tissues of a wide variety of invertebrates, especially in corals, jellyfishes, and radiolarians. These species are known collectively as "zooxanthellae" and are small, degenerate, photosynthetic animals which live and multiply in the tissues of their host. They are able to live free of the host, but rarely do so. Zooxanthellae use the carbon dioxide, phosphorus, and nitrogen wastes of the hosts in order to synthesize food. They yield oxygen to the host and may even be digested by the host when the latter is hungry (Hyman, 1940). The brownish or yellowish color of corals and radiolarians is due to the presence of zooxanthellae. Some coral animals are greenish, and this is due to the presence of zoochlorellae, small, single-celled green algae that live in the hosts' tissues in the same way as do zooxanthellae.

Amoebalike Protozoans: *Class Sarcodina or Rhizopoda—Figure 23*

Among the most delicate and beautiful objects of the sea as well as the largest protozoans belong to this group. All of the species have extensions of their bodies called "pseudopodia" ("false feet") by which they move and capture food. Pseudopodia are neither constant in form nor number, but are best thought of as being tentaclelike extensions which may appear or disappear at any place on the body. How pseudopodia are formed by the protozoan is not known.

The foraminiferans ("hole bearers") are a group of amoebalike protozoans that build calcareous skeletons which are perforated by many minute holes through which the slender pseudopodia extend. The animal starts life with a small shell of one chamber. New chambers of ever-increasing size are added, usually in a spiral fashion (like the growth of snails) until the time of death. Foraminiferans are found in immense numbers from surface waters to the abyssal zone. Their skeletons have accumulated in huge quantities in oozes on the sea bottom. One form, *Globigerina*, has covered 30 per cent of the forty million square miles of ocean floor with its shells (Buchsbaum, 1948). The chalk of England's Dover cliffs, a thousand feet thick, is composed largely of foraminiferan shells. If one considers that upwards of fifty million shells may occur in one pound of bottom ooze, the number of shells on the sea bottom becomes inconceivably great.

Radiolarians are like foraminiferans, but have siliceous skeletons. They have yellow-brown zooxanthellae in them, which probably contribute to their nutrition. The delicate and frequently very beautiful skeletons, as well as oil or fat droplets in the body, and the fine pseudopodia aid these animals in floating at the surface of the ocean. In the very deep parts of the ocean (over 15,000 feet), radiolarian oozes are formed of the skeletons of these animals. Somewhat less than 5 per cent of the ocean floor is carpeted by this ooze. At these depths, the calcareous skeletons of foraminiferans dissolve, leaving only the relatively insoluble siliceous skeletons of radiolarians.

Ciliates: *Class Ciliata—Figure 23*

Ciliates are named and distinguished from all other protozoans by the possession of little hairlike processes called "cilia" which cover their bodies. Most are free-swimming, but some live attached to substrate or are colonial.

There are a great number of marine species, none of which has a skeleton. They are not common as oceanic plankton, but they are very numerous inshore in shallow water or as parasites. The species of ciliates live wholly by hunting down prey or by filtering sea water by means of currents set up around their "mouths" by the cilia. Because of these active modes of feeding, ciliates are the most active of protozoans and show more response to environment than do other protozoans.

One group of ciliate derivatives called "suctorians" has lost cilia and has acquired long tentacles by which prey is captured and sucked dry. Prey usually consists of other protozoans or small larvae of invertebrates and may be several times the size of its captor. Suctorians are very common attached to substrate or to other animals in shallow waters.

SPONGES: Phylum Porifera (*"pore-bearer"*)

Colonial animals are those in which several individuals have banded together to form one functional unit. Multicellular animals are those in which the different cells have become associated into different organs for the performance of different jobs. Sponges sit on the fence between being colonial and multicellular. They probably arose from flagellate protozoans because they are composed of aggregates of flagellated cells, but these cells are not gathered together to form organs. There are several types of cells, some wandering and amoebalike, and there is a supporting skeleton. Therefore, sponges, though they are not on the direct evolutionary line toward multicellular animals, do show how multicellular animals might have arisen through associations or colonies of single cells.

The partial independence of the cells of sponges is demonstrated by the sponges' powers of regeneration. Sponges are a bit like the magical broom of "The Sorcerer's Apprentice." If a sponge is cut into many pieces, each piece is capable of producing a new sponge. It is even possible to separate the cells of a sponge by squeezing it through a fine cloth. These cells, if they are still living, will group together again and grow into a new sponge.

Sponges are very plantlike and, in fact, were not known to be true animals until the nineteenth century. Basically, a sponge is a hollow vase perforated by holes (hence the name "pore-bearer"). There are many small holes by which water enters the vase and one larger hole, or a few larger holes, by which water leaves. The latter are large enough to be easily seen by the naked eye. Currents of water through the vase are caused by the beating of the flagella of the cells on the inside and bring microscopic, planktonic food to the cells of the sponge. In most cases, sponges are not merely simple vases, however, but have become much infolded and complicated in form, so that the internal surface area of the sponge is greatly increased without involving much of an increase in size.

Sponges have skeletons composed of calcium carbonate, silica compounds, or spongin fibers. The first two are brittle and in the form of delicate, needlelike, branching spicules which are enmeshed together to form the sponge's supporting structure. Spongin is resilient and is the substance known to us all as the fibers of the bath sponge, *Euspongia*. It is largely on the basis of their skeletons that sponges are classified.

Sponges exist in a wide variety of shapes. Some are small and even parasitic. Others, such as the Pacific Neptune's cup, *Poterion*, are big enough to sit in. In general, sponges are like plants in growth pattern. For instance, a tree has a pattern of growth by which it may be recognized, but there is no set number of branches it must have. The same is true of sponges in that there are branching, erect, encrusting, or vaselike patterns of form, but each species shows considerable variation within that form.

The great majority of sponges are marine, there being only one small fresh-water group. Sponges are largest and most varied in shallow, tropical waters. Almost everywhere that they are found, a host of other animals, mostly worms and crustaceans, are associated with them, living in the cavities for protection. The most notable of the sponge symbiotic relationships exist between several species of hermit crabs and a few species of a family of horny sponges. The sponge grows on the shell occupied by a crab and eventually grows to cover the entire shell. Then the sponge dissolves the shell away and itself forms the home of the hermit crab. This is a case of mutualism in which the crab is protected from predators by the bad taste of the sponge and the sponge benefits by receiving transportation. Although most sponges taste and smell badly and are protected by their sharp spicules, two groups of animals, the nudibranch molluscs or sea slugs and the sea spiders, have some species that eat sponges. The sea slugs frequently imitate sponges in shape and color. The sea spiders suck the juices of sponges.

Calcareous Sponges: *Class Calcarea—Figure 24*

These are the simplest sponges, small and vaselike, either single or grouped in colonies, yellowish to whitish or muddy in color, and with spicules of lime.

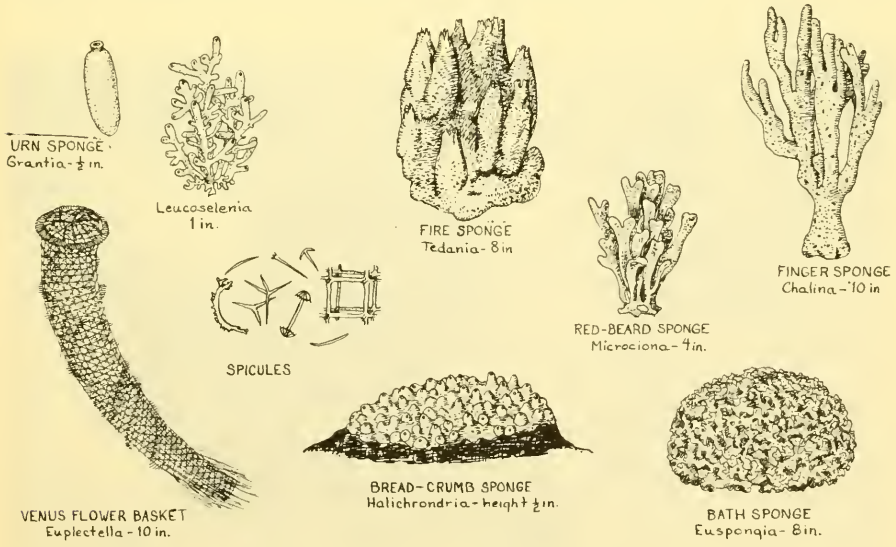


Fig. 24. Sponges. Drawn from life.

Almost all of these sponges are found in shallow temperate waters on pilings or rocks or in tidepools. *Leucoselenia* is one of the most common of the colonial or branched forms, and *Grantia* is an "urn sponge." Both of these rarely reach over an inch or two in height. The distribution of these sponges is world-wide.

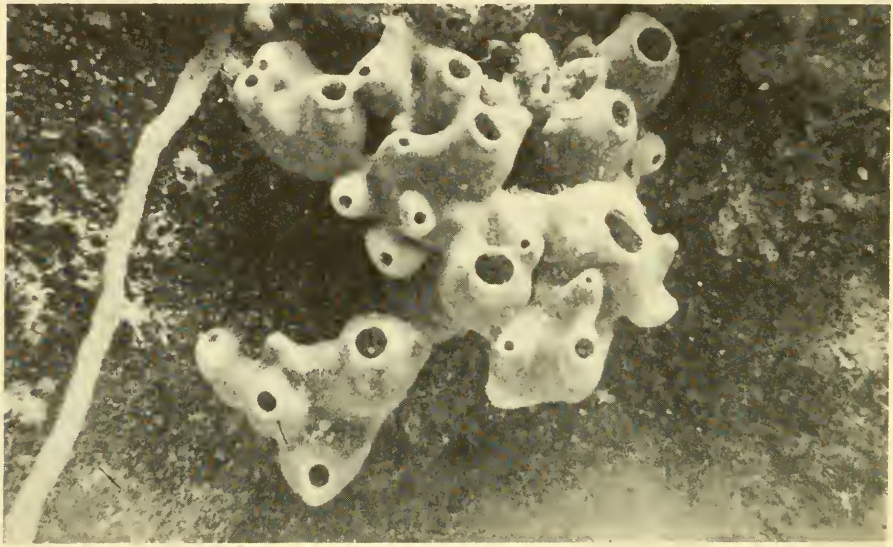


Fig. 25. Top. This colonial vase sponge, three inches high, has large holes called excurrent openings through which water, taken in through many minute holes in the sides, leaves the animal. Bottom. The basket sponge, Hircina, *anchored on a small coral outcrop and almost large enough to sit in, is the largest species of sponge in North American waters.*

Glass Sponges: *Class Hexactinellida—Figure 24*

These are mostly vaselike sponges of deep water. The skeleton is formed entirely of six-rayed spicules of silicon compounds. Since most of them must anchor in the mud of deep water, there is commonly a rooting tuft of elongated spicules at the base of the sponge. The skeletons are frequently extremely beautiful glassy objects like that of the Venus flower basket, *Euplectella*. This group is found in deep water of all seas but is most common in the tropics.

Horny Sponges: *Class Demospongiae—Figure 24*

The great majority of sponges belong here, and most sponges encountered by the diver will be of this class. The skeleton is largely formed of spongin fibers, which gives a breadlike texture to most of them. Some of them, however, have siliceous spicules (never six-rayed as in glass sponges), and a few have no spongin but only have siliceous spicules. Some of the species have echinating spicules, that is, the spicules are sharp and break off in whatever object they touch. The fire sponge, *Tedania*, and the poison-bun sponge, *Fibulia*, are two of these. The fire sponge is shaped like the red sponge (*color photograph*), but it is usually a much more brilliant reddish orange in color. The poison-bun sponge is breadlike in texture, brownish in color, and grows in rounded clumps like many common sponges. Both of these are West Indian and capable of producing more or less severe burning stings. Because of the irregular shape of many sponges, it is hard to recognize some of the species, so it is a good precaution to wear heavy gloves when handling them.

The colors of horny sponges vary widely from the yellow bread-crumb sponge to the brilliant red of the fire sponge and the red-beard sponge, the purplish red of the red sponge, the green of some boring sponges and vase sponges, and the drab brown or black of bath sponges and basket sponges. The form of horny sponges is even more variable. The bread-crumb sponge, *Halichondria*, and boring sponges, *Cliona*, which can bore into the shells of molluscs or into rocks, are encrusting; the red-beard, *Microciona*, and the finger sponge, *Chalina*, are erect and branching; many are like vases and are colonial (*fig.* 25 and *color photograph*); the bath sponges, *Euspongia*, are rounded; the basket sponge, *Hircina* (*fig.* 25) is cup-shaped and almost large enough to sit in. Almost all of these types have extremely wide distribution, but horny sponges are most varied and are largest in the tropics. The area of the Bahama Islands is especially rich with them.

POLYPS AND MEDUSAS: Phylum Coelenterata

These are the jelly animals—jellyfishes, hydrozoans, gorgonians, corals, anemones—so named because of the presence of a jellylike substance, consisting of about 98 per cent water, which is found between their outer (ectoderm) and inner (endoderm) layer of cells. These are the lowest members of the animal kingdom which have cells organized into organs—digestive, muscular, nervous, reproductive—and they also show, for the first time, a nervous system. This is a very primitive system with no brain and consists only of a network of nerve

fibers, but it does allow coordinated muscular action so that these animals can perform simple coordinated movement, such as contraction of the animal as a whole or movement of tentacles.

Basically, there are two types of body form in this group, the sessile polyp and the free-swimming medusa. Actually, these two are merely two forms of the same thing, the polyp being long of body with the mouth up and the medusa being short and turned over with the mouth down (*fig. 26*). The primitive species have both of these forms present in an *alternation of generations,* a name given for the extraordinary breeding method in which the polyp reproduces asexually by budding to produce medusas and the male and female medusas reproduce sexually by union of egg and sperm to produce more polyps. The whole phylum is divided into classes on the basis of which one of these generations, the polyp or the medusa stage, has become dominant. Because medusas are active and free-swimming, they show greater responsiveness to environment than do polyps.

All of the species of coelenterates are united by the possession of two characteristic features. First, they are radially symmetrical; in other words, the top of the body differs from the bottom, but all the sides are the same. Second, most have unique stinging structures called "nematocysts" (*fig. 26*), which, in response to a touch on a trigger (cnidocil), are able to shoot out a piercing barbed thread, injecting poison into the object with which it comes into contact. The poisonous thread acts like a fish line, holding the prey to the tentacle. One nematocyst by itself would not be very potent in either poisoning or holding prey, but as the prey struggles, it becomes more and more enmeshed in nematocysts and is subdued shortly. Some nematocysts are large and powerful enough to cause serious poisoning to man, particularly those of the Portuguese man-of-war and the lion's-mane jellyfish. These cells are the organs of offense and defense of coelenterates.

Coelenterates are found in great numbers all over the world in shallow to deep waters. Some eat fishes, some feed by filtering plankton, and some have food manufactured for them by other organisms living in them (symbiotic zooxanthellae or zoochlorellae). Some of them are very striking because of the beauty of their skeletons, as in corals, or the beauty of the iridescent blues, yellows, and reds of their bodies, as in anemones and jellyfishes. As unattractive as jellyfishes may be lying dead on a beach, in the water they are very beautiful as they move by gentle, rhythmic pulsation of their translucent bells, their tentacles streaming gracefully behind. But the diver should not be too carried away by the beauties he finds in this phylum. While most are harmless, many can produce painful stings.

Hydrozoans: *Class Hydrozoa—Figure 27*

This is a group of great variation, having species that show alternation of generations between polyp and medusa stages and those that are exclusively polyps or medusas with no alternation of generations. There are twenty-seven hundred species of hydrozoans in all waters of the world.

The hydroids are the most typical of the hydrozoans, showing typical alternation of generations. Most of them are small, colonial, plantlike, branching, and have a skeleton of a stiff, horny material (though some are without

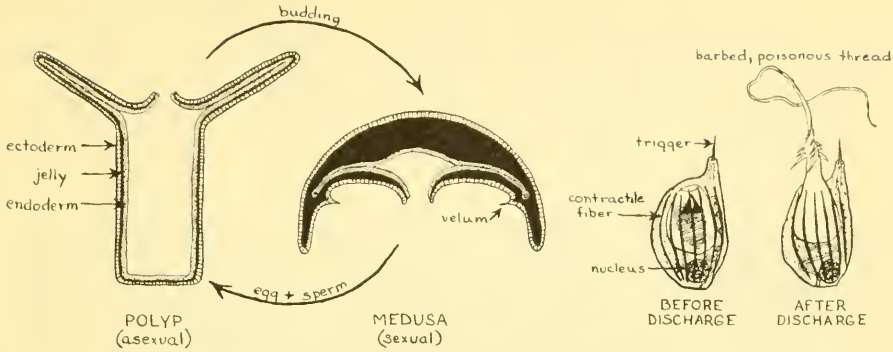


Fig. 26. The alternation of generations of a typical hydrozoan coelenterate is shown on the left. The asexual polyp and sexual medusa exhibit the same general body plan except that the medusa is greatly shortened, inverted, and has much more jelly than the polyp. Coelenterate nematocysts, on the right, fire a poisonous thread into prey or enemies on contact.

skeleton). These are among the most common of seashore animals, but they usually go unnoticed because of their small size. Among the many genera of small hydroids is *Obelia*, which shows, among its branches, two kinds of polyp animals, a feeding one with tentacles and a reproductive one which produces the sexual medusas by budding. At some times of year these little hydroid medusas are very plentiful.

There are many species of small hydroids like *Obelia*. One of these is *Hydractinia*, which is commonly found on the shells of hermit crabs (*fig.* 38), a case of mutualism in which the crab receives protection from enemies because of the presence of the stinging hydroid tentacles and *Hydractinia* gets free transportation. Most hydroids are too small to sting man, but a few have very large nematocysts which are painful to touch. Phillips and Brady (1953) list *Lytocarpus* of the eastern coast of Florida and southward as one of these. This is a small colonial species like *Obelia* and grows on rocks and pilings among seaweeds. Treatment for the sting consists of thorough washing with soap, followed by application of ammonia or calamine lotion to soothe the burn.

Tubularia, of temperate waters, is a beautiful reddish-pink hydroid that grows unbranched out of a mat and reaches a height of almost 6 inches. The most common small hydroid of the West Indies is *Pennaria* (*fig.* 29), which looks like a small Christmas tree. Not all hydroids are small, however. One gigantic, noncolonial polyp, *Branchiocerianthus*, reaches 6 feet in length and lives in the ocean depths.

The stinging coral, or fire coral, *Millepora* (*fig.* 28 and *fig.* 144), is not a true coral, but is a hydrozoan related to hydroids. It grows in a great variety of forms—branching, erect and bladelike, massive, or encrusting (often on sea fans). They have dense, limy skeletons with very small pores through which the polyps project. Stinging corals are major contributors to the formation of reefs in all tropical seas. The sting of the West Indian species is only moderately painful and the effects usually wear off in a few hours. Indo-Pacific fire coral can produce more painful stings.

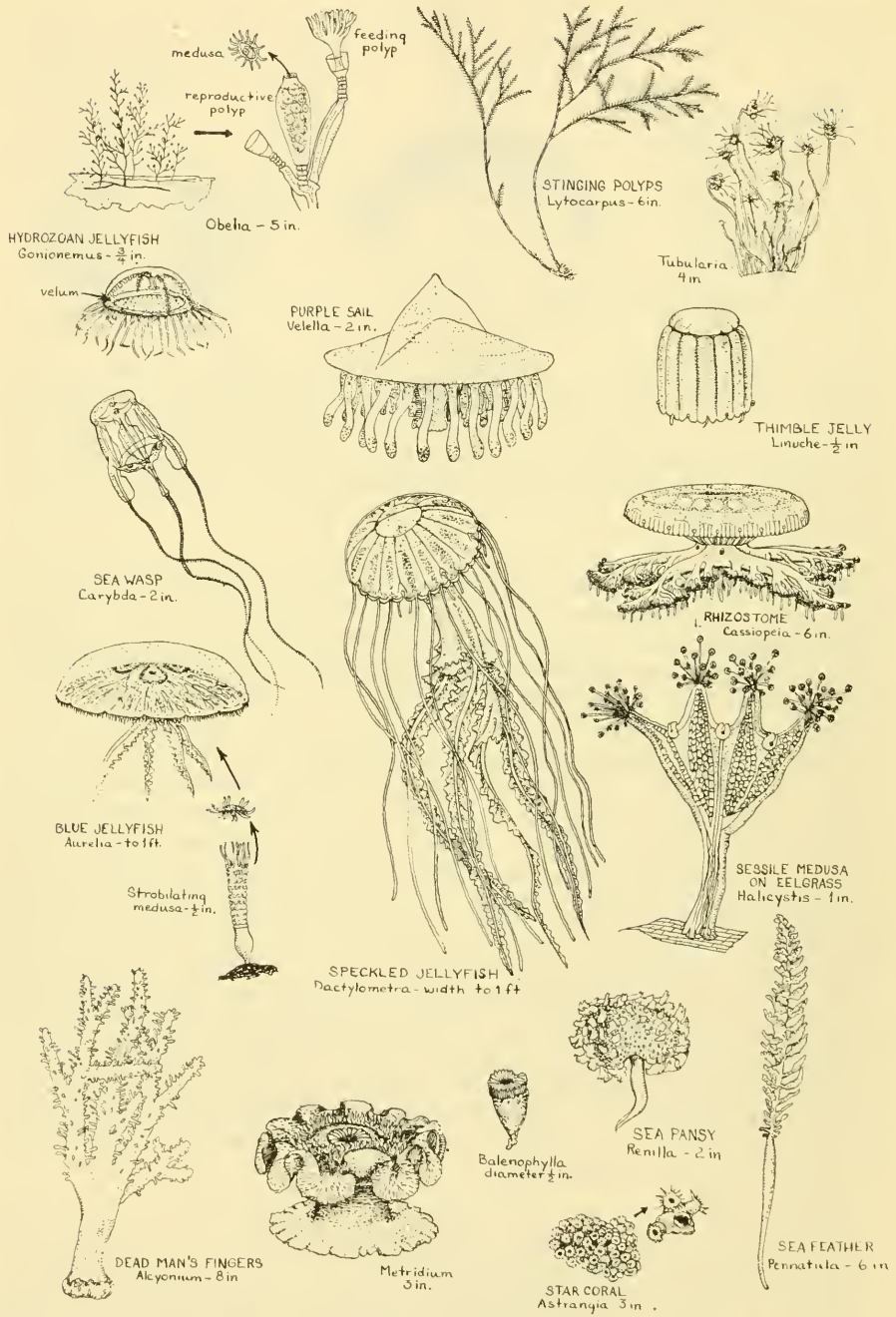


Fig. 27. Polyps and medusas. Adapted from Mayer (1910) and drawn from life. See Color Plate 10.

Trachyline hydrozoans are all medusas and look like true jellyfish. (One species, *Geryonia*, is shown in Color Plate 10.) They have no polyp stage, contrary to most hydrozoans, and are small to moderate in size, not reaching more than 4 inches across the bell. They may be distinguished from true jellyfish by the presence of a shelf called the "velum," projecting inward from the lower bell margin (*figs.* 26 and 27).

Fig. 28. *Stinging coral,* Millepora, *takes on a number of forms including that of these foot-high blades, but it is most easily recognized by its mustard-yellow color and knobby texture. In the background is a large bush gorgonian.*

Fig. 29. Top. Pennaria, *a form of colonial hydrozoan, is only an inch high and looks like a Christmas tree. Each of the white knobs is the head of a single animal. The tentacles are too slender to be seen. Bottom. Sea whip gorgonians, unlike most anthozoans, "bloom" by day to capture their planktonic food. Each animal is barely one-fourth of an inch in diameter.*

The last of the hydrozoan groups is that of the Portuguese man-of-war, order Siphonophora. These are not single animals as is commonly supposed, but are floating colonies consisting of several kinds of medusas and polyps living together. One medusa forms the bell or float of the colony. Other medusas form swimming bells, which move the colony through the water. The polyp members of the community contribute the feeding individuals, tasting or feeling individuals, stinging individuals with nematocysts, and reproductive individuals. Thus, a siphonophore is actually a complex colony of many kinds of individuals all specialized for different functions. Not all kinds of individuals may be present in a colony. For instance, the Portuguese man-of-war, *Physalia* (*Color Plate 10*), lacks medusoid swimming bells and depends solely on the wind for distribution.

All of these colonial siphonophores are pelagic. Most are small and delicate, but the purple sail, *Velella*, and the Portuguese man-of-war are rather large. Of these, the latter is famous for the power of its large nematocysts. Bad stings can cause cramps, nausea, difficulty in breathing, or, very rarely, death. One of the authors received the stings of only two nematocysts in his heel. In very short time, the poison had traveled to the region of the groin, making walking painful. Bad stings should receive immediate medical attention. The man-of-war reaches a size of a foot across the float and with tentacles over 30 feet long. It is thus able to catch a fish the size of a mackerel.

True Jellyfishes: *Class Scyphozoa—Figure 27*

This is a rather small, compact group of only two hundred species. No true jellyfish has a velum as do the hydrozoan jellyfishes. Most have polyp generations of small size, which produce medusas by a type of budding (strobilation) during the warm months. These are the common, large medusas and are found in all seas, particularly those of temperate and cold zones. They are common objects cast up on beaches. (A typical species, *Pelagia*, is shown in Color Plate 10.)

The true jellyfish common in warm or tropical seas are the cubomedusans, which are named for the high, squarish or cuboidal shape of the bell. At each corner of the bell is a single tentacle or group of tentacles. *Carybdea* is a common example. It is an inshore jellyfish, a strong swimmer, a fish-eater mainly, and has a strong sting. Most cubomedusans are only 1 to 2 inches across, but some reach 10 inches. Their sting has given them the name of "sea wasps."

The discomedusans are the typical jellyfishes which are most common in temperate and cold waters. They have round, hemispherical bells and are the largest of all coelenterates. One species, the lion's-mane jellyfish, *Cyanea*, reaches a diameter of 8 feet or more with tentacles 200 feet long. Huge shoals of this animal are common in arctic or boreal seas, but, luckily, large ones do not range far south. They possess a dangerous sting because of their large size. The blue jellyfish, *Aurelia*, is the most common jellyfish of the Atlantic and Pacific. This genus reaches a foot across the bell and can produce an irritating sting. *Pelagia* and *Dactylometra*, the speckled jellyfish, are two very beautiful and delicate discomedusans of temperate to tropical waters. Both can produce painful stings. The former is only a couple of inches across, but the latter reaches up to a foot in width.

The rhizostomes are jellyfishes without tentacles and are common in shallow

tropical waters. One in particular, *Cassiopeia*, is common in the West Indies. It has no true single mouth and cannot sting, but it possesses a much-divided and lobed digestive system which contains symbiotic algae. This jellyfish is often seen lying lazily upside down in shallow water, exposing the algae to sunlight. The algae, therefore, produce some of the food for this jellyfish by photosynthesis. All rhizostomes have the many-lobed digestive system like *Cassiopeia*, but most have no algae in them and therefore must live by catching plankton or small fishes.

The young of many fishes use jellyfishes for protection, escaping the tentacles by alertness. Sometimes, however, they fall prey to their jellyfish protectors.

Gorgonians, Anemones, and Corals: *Class Anthozoa—Figure 27*

There is no medusa stage at all in this group. Instead, the polyp has become complex and either secretes a home around itself and is colonial or is large in size and solitary. There are over six thousand species of anthozoans found in all seas, but they are far more common and larger in tropical seas than elsewhere. The colors found in this group are often very beautiful and caused partially by pigment and partially by the presence of organisms, zooxanthellae and zoochlorellae, that live in the tissues of the polyp. Hard corals are most often brownish, but they may be green, blue, or, in the case of the Mediterranean precious coral, *Corallium*, a gorgeous red. The sea pen is red and phosphorescent. Gorgonians are brownish. The browns, yellows, and greens are the colors caused by symbiotic animals and plants. Most coral skeletons are white like coral sand.

All of the members of this group are carnivorous, but the size of the prey varies greatly, and in many, the oxygen supply is augmented by the presence of zoochlorellae or zooxanthellae. The small, colonial anthozoans eat planktonic food, and the largest polyps, the anemones, catch fish or whatever else they can trap in their stinging tentacles. All are sedentary, though anemones can creep very slowly on their bases, and must wait for food to come their way. They either feed by passively filtering sea water or by attracting fishes with their flowerlike body form and colors. Some anemones even have little fishes living symbiotically in the protection of their tentacles, and these may serve to attract other fishes near enough to be caught. In any case, food is not acquired actively by the tentacles as in the case of the octopus. A fish must bump into a tentacle through its own carelessness to be captured.

Many of the anthozoans, notably the corals, are nocturnal. With the coming of dusk, the coral colony blooms as thousands of tiny polyps emerge from their calcareous homes. This seems to be somewhat a contradiction of the fact that light is needed by the zooxanthellae that produce oxygen for the coral, but enough light is probably able to reach the retracted polyp to allow photosynthesis to occur.

Very few members of this group possess nematocysts large enough to do damage to humans. Only one large anemone of the Indo-Pacific is really dangerous. Others may produce a barely perceptible burning when touched. Corals, however, may inflict cuts that are slow to heal and become easily infected. This is known as "coral poisoning" and is not very prevalent in North America. Ergophine ointment is said to be of use in alleviating the irritation of coral cuts.

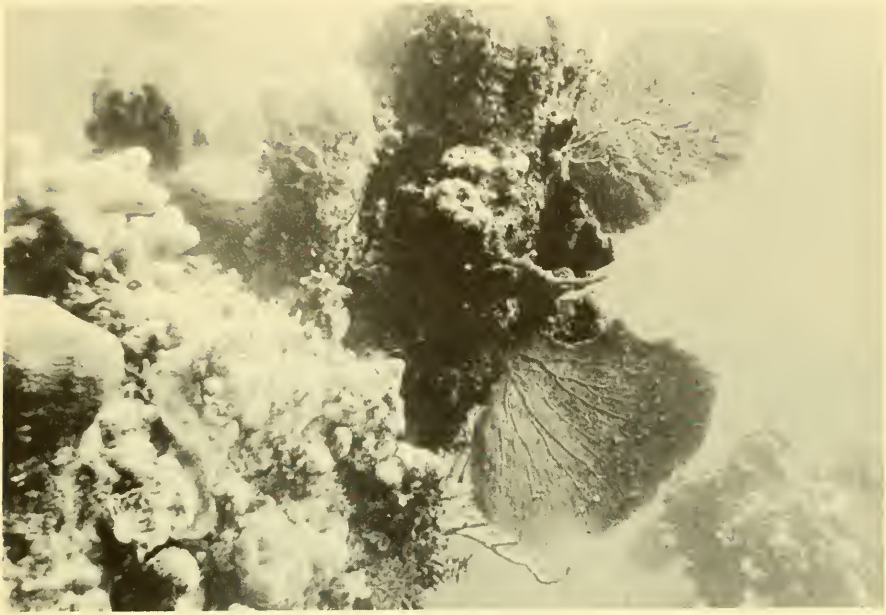


Fig. 30. Top. Sea fans, Gorgonia, *over a foot in diameter, often anchor to pedenculate coral in fairly calm water. Several small corals may be seen to the left, including a blue coral (top left). Bottom.* Eusmilia *is one of the most beautiful corals. The colony is not large, but each coral polyp is of good size, up to three-fourths of an inch in diameter.*

Among the several groups of non-stony corals, the gorgonians are the most prominent. These are the bushy sea whips (*figs. 28, 29, 97, 144*) and sea plumes (*figs. 97, 148*) and sea fans *Gorgonia* (*fig. 30*). Sea whips and sea plumes have a resilient skeleton composed almost entirely of a horny material called "gorgonin" and because of their toughness often form dense beds in places where wave action would break stiff, stony corals. The beautiful iridescent, purplish sea fans add a considerable amount of lime to the skeleton. Being less resilient, they more often grow attached to stony corals in calmer waters. The precious red coral, *Corallium*, of the Mediterranean is a member of this group whose skeleton is composed almost entirely of lime of a bright red color.

Fig. 31. Top. Brain coral, Meandra. *Female blue-head wrasse often cluster around the tops of large corals like this very large and almost perfectly symmetrical specimen. Bottom. Staghorn coral,* Acropora cervicornis, *forms extensive thickets where many fishes make their homes.*

Gorgonians are secondary reef builders and are largely tropical in distribution. Several animals live in their bushy branches. Among these are the basket star, *Gorgoncephalus*, hydroids, oysters, and some others.

Dead man's fingers, *Alcyonium*, is representative of a group of anthozoans called "soft corals." It is usually found in rather deep water, but it reaches up to the low-tide mark. It has a flabby, mushroomlike texture supported by calcareous spicules. Soft corals vary in shape from squat, spongy masses to erect, treelike, branching forms and are found in all seas, but they tend to keep to fairly deep water.

The pennatulaceans include the very beautiful sea pansies, *Renilla*, and sea feathers, *Pennatula*. Both of these have a long single polyp that forms the axis of the colony and which serves to anchor the colony in soft substratum. This axis can move the colony slowly or withdraw the colony into the bottom when it is disturbed. These are the most active of the anthozoans. On both sides of the axis, there are extensions that carry the small feeding polyps. Most species are beautiful shades of yellow, red, or purple and inhabit shallow, tropical, and subtropical waters of all seas. Many of them are luminescent and will give off light when disturbed.

The anemones form a fairly compact group of anthozoans. They are devoid of a skeleton and are noncolonial and flowerlike. Their distribution is world-wide in all seas, and they are almost always found attached to hard, rocky, or coral reef bottoms, where they sit waiting for prey to blunder into their tentacles. The size range is from less than an inch to 2 feet in diameter. Anemones usually avoid bright light and can move slowly on their bases more or less like a snail. They like to attach themselves in crevices, with only the tentacles exposed. Their colors are often extremely beautiful, ranging from bright green to white or dark brown with delicate blues and reds. Anemones are able to contract greatly in size, and when they do so the tentacles are drawn inside, which makes them difficult to spot. (The common West Indian anemone is shown in a *color photograph*.) *Metridium* is the most common temperate Atlantic species. The west coast green anemone, *Cribina*, owes its color to the presence of zoochlorellae. *Adamsia* (*fig.* 38) is a remarkable anemone that lives in a mutualistic relationship on the shells of hermit crabs, giving the crab protection by means of its nematocysts and even patching holes in the shell the crab occupies (Hyman, 1940). The anemone benefits by receiving food and transportation. Several other anemones live in similar mutualistic symbiosis with crabs.

The true or madreporite corals are like small anemones but are colonial and secrete calcium carbonate (lime) around their bodies for protection. (Their environmental requirements are discussed in Chapter 2 under coral reefs.) Corals are found north to temperate waters, but form reefs only in the tropics. Star coral, *Astrangia*, is one that is found north to Cape Cod. Corals show a great variety in form. Some are small like star coral, some are massive like several kinds of stone coral (*color photograph*), and the brain coral, *Meandra* (*fig.* 31 and *color photograph*), some are stump-shaped like pedunculate corals (*fig.* 30), and some are branching like the staghorn coral, *Acropora cervicornis* (*fig.* 31), or the antler coral, *Acropora palmata* (*color photograph*). There are many species of small decorative corals. One is *Eusmilia* (*fig.* 30), an extremely beautiful coral, which has large polyps even though the colonies are quite small.

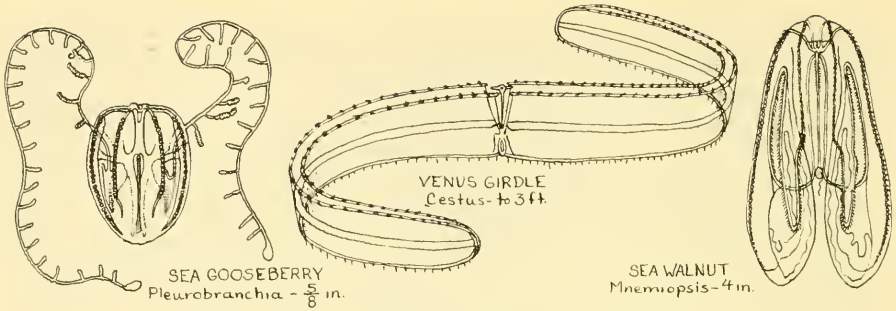


Fig. 32. Comb jellies. Adapted from Mayer (1912).

On the West Coast is found the solitary coral *Balenophylla*, which reaches a half-inch in diameter.

COMB JELLIES: Phylum Ctenophora (*"comb-bearer"*)—*Figure 32*

There are only a few species of these exceedingly beautiful animals, but these often occur in tremendous numbers and are common in all seas. Their transparent bodies shimmer with delicate colors of glassy, iridescent beauty and bear eight comblike rows of cilia which move the animal through the water and have given these animals their name.

Ctenophores are exclusively pelagic, predatory animals. They catch planktonic prey or small fish by means of two long retractile tentacles that extend from the sides of the body and which bear sticky "lasso cells." Some have no tentacles and filter plankton from the sea.

Almost all the species have very wide distribution. The little sea gooseberry, *Pleurobranchia*, is found in all the seas of the world. The sea walnut, *Mnemiopsis*, is like the sea gooseberry, but it is larger and is luminescent. If a boat is driven through a swarm of them, the disturbance causes each one to emit a bright, sudden flash of light. The Venus girdle, *Cestus*, is very different from these, being elongate and like a ribbon. It reaches a length of 3 feet occasionally but is usually seen much smaller.

FLATWORMS: Phylum Platyhelminthes—*Figure 33*

Flatworms are not common or prominent in the sea, but are very well known as parasites—the flukes and tapeworms. One group of small flukes, the schistosomes or blood flukes, has a larva that normally infects sea birds. It is also able to burrow partially into human skin, where it forms an extremely itchy swelling known as "swimmer's itch" or "seabather's eruption." These larvae die soon after entering the swimmer's skin, so do not produce parasitic infection in man. Phillips and Brady (1953) suggest immediate fresh-water bathing plus application of dilute ammonia or antihistamines for relief of the itching.

Not all flatworms are parasitic. The turbellarians are flattened, frequently leaflike worms that creep about among plants or over the bodies of marine animals such as crustaceans. They possess amazing powers of regeneration. If the head of a turbellarian is cut off, the headless body grows a new head, and

the bodyless head grows a new body—result: two worms. If the head is cut longitudinally in two the result is the regeneration of two heads.

Almost all free-living flatworms have two eyes on the head which are turned in, making the animal appear cross-eyed. These eyes do not form an image, but inform the worm of the presence of light or dark. In general, flatworms avoid light. They feed on organic matter of all sorts, which they locate by means of chemical reception. Flatworms either glide on their bellies by means of cilia or swim by body undulations.

The acoel flatworms have no digestive system and range up to a half-inch in length. The red *Polychoerus* is found in the tidal zones of both coasts. *Convoluta* is a green acoel that derives its color from zoochlorellae in its body. This animal may feed when young, but when it becomes adult, it lives entirely by digesting the zoochlorellae, which results in the death of the worm, an example of poorly balanced mutualism (Buchsbaum, 1948).

Rhabdocoel flatworms have a straight intestine and are very common on muddy and sandy shores or seaweeds. The triclads have three-branched intestines, are of dark color, and are most common on stony bottoms of northern seas. Both rhabdocoels and triclads rarely reach a half-inch in length. *Bdelloura* is a triclad common on the gills of the king crab, *Limulus*.

The polyclads have many-branched intestines and reach a length of a half-foot or more. The tropical ones are frequently very beautiful, matching their surroundings in color. Some polyclads are pelagic. They swim by means of wavelike motions of the sides of the body.

All of the flatworm groups mentioned show tendencies toward commensalism, suggesting that the parasitism so common in other flatworm groups, such as flukes and tapeworms, evolved first from commensalism. The end product of parasitism is often mutualism which, however, is not present in flukes and tapeworms.

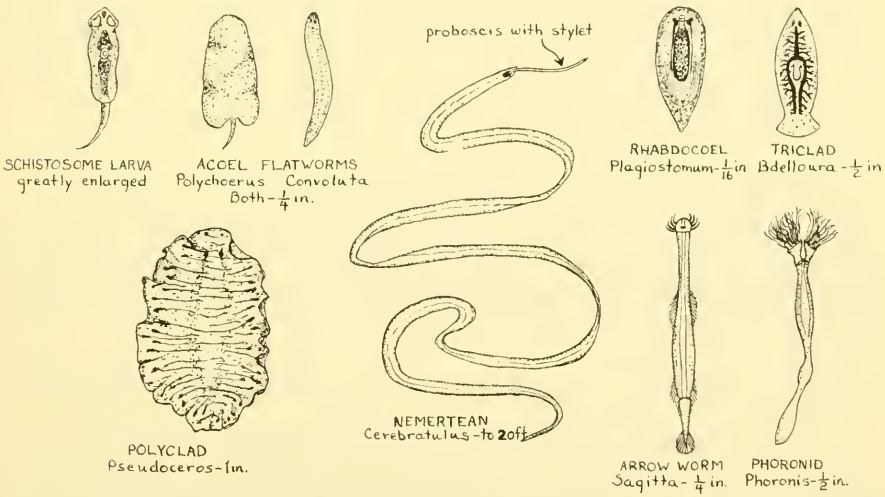


Fig. 33. Unsegmented worms. Adapted from several authors and drawn from life.

RIBBON WORMS: Phylum Nemertea—*Figure 33*

These are the lowest members of the animal kingdom to have a circulatory system through which blood flows and a digestive system with a separate mouth and anus. Both of these characters are of immense importance, allowing animals to be more independent in their environment. The presence of blood, by which food and oxygen are distributed throughout the body, and an anus, which frees the mouth of the task of egesting undigested food, gives greater freedom of action to an animal by increasing general body efficiency.

The seas contain 550 species of nemerteans, which range from an inch to 100 feet long. The long ones, however, are not much thicker than a piece of ordinary string. On the head end is a sheath bearing a long noselike proboscis. At the tip of the proboscis a sharp stylet which resembles the nematocysts of jellyfishes is usually present. The proboscis is shot out at prey like an entangling lasso, and those nemerteans which have a stylet use it to poison the prey. Worms, fishes, or crustaceans may be captured and are swallowed whole. The proboscis may also be used for defense and for burrowing.

Nemerteans are found all over the world from the arctic to tropic seas. The largest in North America is the flesh-colored *Cerebratulus* of the temperate east coast. It reaches a length of 20 feet and burrows in sandy or muddy shores by day, but it may swim about at night near the bottom. It is very common and is often dug up by clam diggers. Other nemerteans are as numerous as *Cerebratulus*, and some are very beautifully colored with bright red or green stripes and bars. A few species are pelagic.

ARROW WORMS: Phylum Chaetognatha (*"bristle-jawed"*)—*Figure 33*

These are swift-swimming, predatory, planktonic worms which reach the small size of only about ¼ of an inch and are extremely common in cold temperate and arctic waters. They capture small planktonic animals in their bristly, hooked jaws. There are about thirty-five species. *Sagitta* is the most common genus. Their evolutionary position is not known.

ROTIFERS: Phylum Rotifera (*"wheel-bearer"*)—*Figure 34*

These little animals are extremely interesting to watch, but unfortunately a microscope is needed since their size is about that of a large protozoan. Some rotifers have the most extraordinary shapes and are very common attached to objects in shallow water. Some are pelagic.

MOSS ANIMALS: Phylum Bryozoa (*"moss animal"*)—*Figure 34*

Some of these little plantlike animals are so similar to the hydroid coelenterates that the two groups can only be distinguished by an expert with a microscope. As their name implies, they look mossy. They are colonial. Some are erect and branching, and others are flat and encrusting in form. All are enclosed in an external skeleton, which gives the colony support and may be

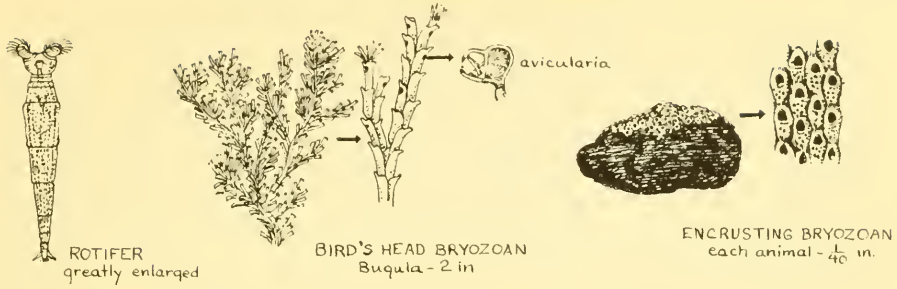


Fig. 34. Rotifer and bryozoans. Adapted from several authors.

either horny and flexible or heavily calcified and stiff. Bryozoans feed by filtering plankton out of sea water by means of a crown of tentacles called a "lophophore."

The bird's head bryozoan, *Bugula,* is a common and very widespread form found in most waters of the world. It looks like a small brownish tuft of moss, is 2 to 3 inches high, and grows anchored to almost any hard bottom in shallow water. Some individuals of the colony are reduced in size and look very much like the head and beak of a bird. These are called "avicularia" and constantly move from side to side snapping at any object that lands on the colony, keeping the colony free of foreign matter. Living *Bugula* seen under a microscope show these amusing little individuals very well.

An amazing habit of many moss animals is the formation of the brown body. Periodically, the tentacles and anterior digestive system of a single animal degenerate into a brown clump which is ejected through the anus. Then a new set of internal organs is regenerated. No reason for this is known. The bryozoa lack a circulatory system, and their evolutionary position in the animal kingdom is not known.

PHORONID WORMS: Phylum Phoronida—*Figure 33*

The genus *Phoronis* with a very few species comprises almost all of this phylum. These worms are small, usually about a half-inch in length, and are like moss animals in habits and appearance except that they are adapted to live in straight tubes in shallow mud or sand flats rather than attached to hard substrate. Also, they are not colonial, although they are frequently found grouped together. They have a tentacle tuft (lophophore) and filter plankton from sea water as do moss animals. While they are not common on the east coast, they are fairly abundant on the west coast.

SEGMENTED WORMS: Phylum Annelida

The worms whose bodies are divided into segments are called "annelida" which means "ringed." In some of these worms, like the sandworm, *Nereis,* the rings, or segments, are obvious, but in others they are less so. This is a huge group of several thousands of species. Segmented worms are evolutionarily

very important as the group which gave rise to the arthropods, the largest of all phyla, which include insects and crustaceans.

This phylum is divided into three major classes—earthworms, leeches, and marine worms. Only the last of these will concern us, the marine worms or *Polychaeta.* Two other small classes, the echiurids and sipunculids, are tacked onto this phylum because they seem to have been derived from segmented worms.

In habits, this group varies greatly, from errant (wandering), predaceous worms to tube-dwelling, sessile plankton-feeding types, but the important thing about segmented worms is that they have a well-developed nervous system and a segmented muscular system so that rather refined movements are possible. This is an important advance over the nonsegmented animals that we have dealt with so far.

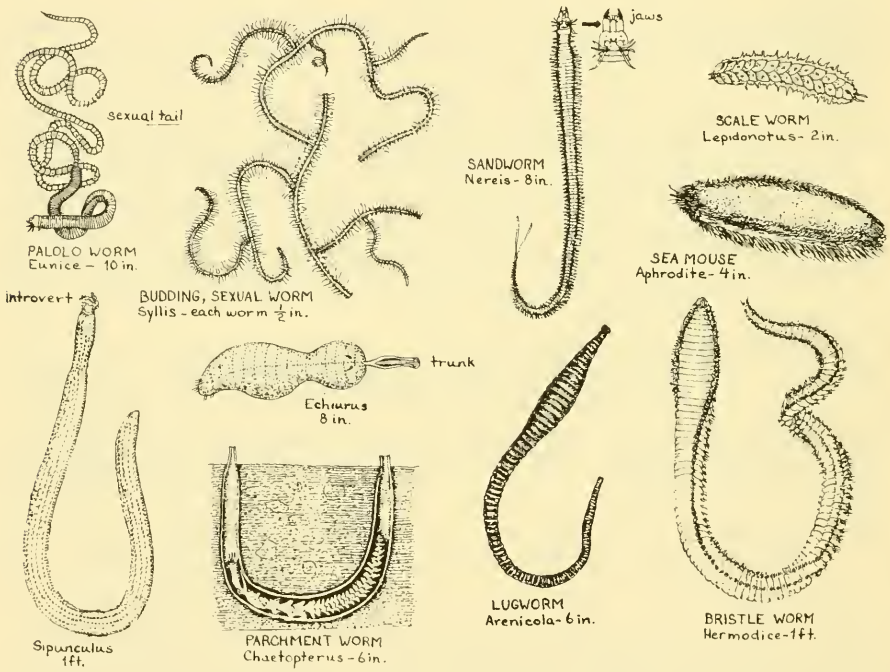


Fig. 35. Segmented worms. Adapted from the Reports of H.M.S. Challenger *(1873–76) and drawn from life.*

Marine Worms: *Class Polychaeta—Figure 35*

The marine worms are obviously segmented, and most of them are provided with appendages on each segment called "parapodia," which bear bristles. Parapodia represent the initial effort made by invertebrates to develop limbs. They function as limbs, as gills, or in food-getting.

The species of this class are extremely common in all seas. They may be rather neatly divided into three groups on the basis of habits—errant or wandering species, burrowing species, and tube-dwelling species.

1. Errant Polychaetes. These marine worms are the most common. They are the most active worms and are armed with a jaw-bearing pharynx which can extend and retract for the capture of living prey. Some of them can swim, but most are found secreted under stones, among weeds, and otherwise hidden from their many enemies which relish their soft bodies for food. The breeding habits of some errant polychaetes are amazing. Most famous is the palolo worm, *Eunice,* one species of which is found in the South Pacific and another in the West Indies. During the last quarter of the October–November moon in the South Pacific or the third quarter of the June–July moon in the West Indies, the bottom-living palolo breaks off its tail (Borradaile and Potts, 1935). The tail, ripe with either eggs or sperm, then swims to the surface of the water, where thick swarms of these reproductive tail ends occur. When eggs or sperm are released, the tail, now an empty bag, dies and sinks to the bottom. Meanwhile, the original head end of the worm on the bottom regenerates a new tail which becomes reproductively ripe the following year.

   Swarming of breeding individuals at the water's surface is common in errant polychaetes. It insures fertilization of a maximum number of eggs since many worms are grouped closely together. Some swarming worms emit a light so that the females and males can more easily find each other. Others have the remarkable ability to bud off new individuals from the posterior end of the body. Each of these individuals can breed but cannot feed since it has no mouth parts. Sometimes a long chain of budding worms may be found at the water's surface during the breeding season. Two of these budding types are *Syllis* and *Autolytus,* both of wide distribution and growing about an inch in length.

   The sandworm, *Nereis,* is perhaps the most familiar of errant polychaetes. There are great numbers of worms found the world over that look like this worm. Some are well over a foot in length, and the larger ones can give a painful bite with their strong jaws.

   The sea mouse, *Aphrodite,* is a mud-dwelling, stout-bodied, very beautiful species with long, silky, iridescent bristles. It reaches 4 inches in length. The scale worm, *Lepidonotus,* reaches 2 inches and is common under stones near shore. These are both stout worms of wide distribution which stay near the bottom.

   One family of errant polychaetes deserves special mention because of the stinging powers of its bristles. This is the Amphinomidae, or the silky bristle worms. There are several species, all of which have long, detachable bristles that easily penetrate skin and cause a burning sensation. These bristles are hard to remove. Phillips and Brady (1953) suggest removing the bristles with adhesive tape. The most common bristle worm is *Hermodice* of tropical waters. It often reaches a foot in length and is warningly colored with red marks on the sides. The white bristles tipped with

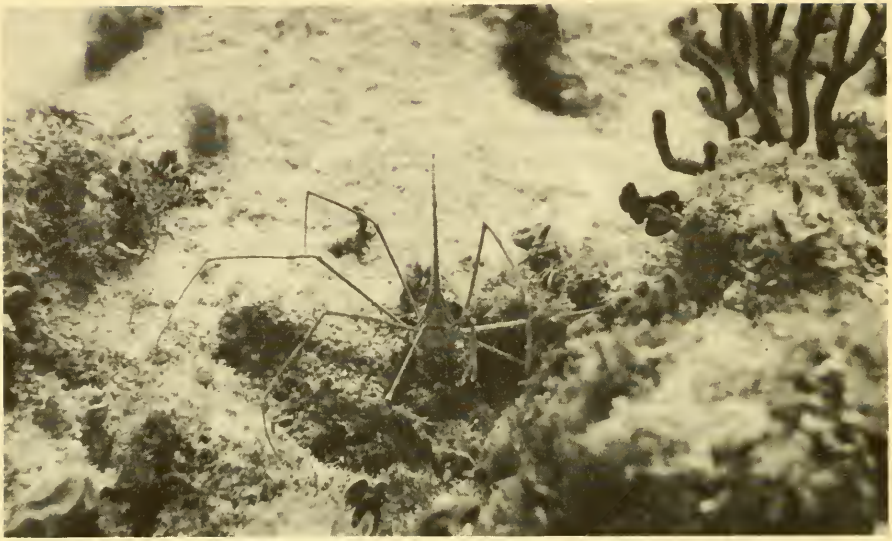


Fig. 36. Top. The arrow crab, Stenorhynchus, *three inches long and named for its long nose, moves slowly and depends on its concealing shape for protection. Bottom. These strange mounds, over a foot in diameter, failed to reveal their builders when the authors dug into them. They are probably built by burrowing polychaete worms.*

red are erected when the worm is annoyed. *Eurythoë* is a west coast bristle worm of pink color and snow-white bristles.

2. Burrowing Polychaetes. These worms have reduced parapodia and head and frequently look very much like earthworms. Most of these worms

travel in soft or loose bottom. The lugworm, *Arenicola,* is common in temperate seas and reaches about a half-foot or more in length.

3. Tube-dwelling Polychaetes. The beautiful fan worms of the family Sabellidae, plankton-feeding worms with a delicate crown of plumes at the head end (*color photograph*), belong to this group. They are found in all seas but are largest in the tropics, where their flowerlike tentacles are often seen protruding from tubes in massive corals. When disturbed, they quickly retract into their tubes.

   The tubes, which are secreted by these worms, may be hard and calcified, as they usually are when in exposed places, but some of these worms live in U-shaped, parchmentlike tubes in soft bottoms. One of these is the parchment worm, *Chaetopterus,* of temperate seas. It is among the most luminescent of animals and is extremely delicate. It circulates water through its tube by flapping delicate appendages in order to filter-feed on plankton.

Sipunculids: *Class Sipunculida—Figure 35*

These are large, sand- or mud-dwelling, burrowing worms of most seas. There is no segmentation to the muscular body. They live in burrows and have at the head end a retractile, tentacle-bearing, muscular "introvert" with which they grasp and swallow mud and sand. They are, therefore, much like earthworms in habits.

Echiurids: *Class Echiurida—Figure 35*

These worms are very much like sipunculids, but instead of an introvert, they have a trunklike extension for feeding. *Echiurus* is a stout-bodied species which lives in a U-shaped tube in mud.

The larvae of the European echiurid, *Bonellia,* have an unusual method of establishing which sex they will be. The larvae are free-swimming. If they land on the trunk of an adult female, they develop into small, parasitic males on that female. If they do not land on a female, they grow into solitary females.

The trunk of echiurids serves both for locomotion and for food-getting. Some species live in soft bottoms and some in clefts in rock, and they frequently move from place to place, not staying in one cleft or tube. They do not eat sand or mud, as do sipunculids, but eat animal and plant matter, probably mostly debris.

ARTHROPODS: Phylum Arthropoda (*"joint-legged"*)

Four-fifths of all species of animals on earth are arthropods (insects, crustaceans, spiders, etc.). They literally abound everywhere, in every imaginable habitat, occupying more different kinds of habitats than any other phylum. For these reasons, arthropods are undoubtedly the most successful animals on earth.

Arthropods are named for their many-jointed appendages. In the primitive species, there is a pair of appendages present on every segment of the body, but in the advanced species, these appendages look very different in different parts of the body, being modified into antennas, various mouth parts such as

mandibles, maxillae, or maxillipeds, claw-bearing "arms," walking legs, swimmerets, and tail "fins" on the abdomen. It is the character and number of the appendages that form the basis of classification of arthropods.

The skeleton of arthropods is well developed and typically formed of a complex substance called "chitin," which sometimes is strongly calcified (crabs and lobsters).

Unlike the skeletons of vertebrates, however, the skeleton of arthropods covers the body rather than forming an internal structure. Also unlike vertebrate skeletons, the external skeleton does not grow but must be periodically shed as the animal grows inside, the new skeleton always being a little larger than the old.

The nervous system and the eyes of arthropods are well developed, allowing interesting and complex behavior. The eyes are compound, that is, are composed of several individual small eyes grouped together yet acting as a unit. They are especially well suited for detecting movement since an object produces an image first on one facet of the eye, then another in succession as it moves across the field of vision.

For the first time in the review of invertebrate phyla, a separate respiratory system is present. This may take several forms—either gills, book "lungs," or tubelike tracheids—but whatever the form, it allows a more efficient respiration than that of previous phyla, which picked up their oxygen through absorption through the surface of the animal. This advance, in turn, allows larger size, higher metabolism, and increased activity.

For all these reasons the arthropods are well-protected, active animals which have complex behavior. The crustaceans form the most numerous group of arthropods in the sea.

Crustaceans: *Class Crustacea—Figures 37 and 38*

All crustaceans have three rather definite parts of the body—head, thorax or trunk, and abdomen. Sometimes the head and thorax are united into a single unit, as they are in crabs and lobsters, and covered by a single "shell" called the "carapace." Crustaceans have a larval stage called a "nauplius" (*fig.* 37), which is common in plankton and is often an extremely bizarre little animal. It is by means of larvae that many crustaceans are distributed through the seas.

The primitive crustaceans are filter-feeders which sift plankton from sea water. More advanced species are carnivores or scavengers. In fact, the crabs and lobsters are the vultures of the sea, eating literally any organic material, living or dead, that they can lay a claw on.

Some crustaceans have good powers of defense in their very strong claws. Others are protectively colored or shaped to mimic rocks or seaweeds. Still others can change color so as to match the lightness or darkness of the bottom. Many of the highly developed crustaceans have a remarkable defense involving intentional loss of a limb or autotomy. If a limb is seized by an enemy, the crustacean snaps it off, then retreats, later growing another limb.

This class occupies a vital place in the economy of the sea. Many of its species form the major food source of many animals. Notable among the many examples is the dependence of the baleen whales on the Euphausian decapods

called "krill." Man, when he speaks of possible future food from the sea in terms of "plankton cakes," usually means the small planktonic crustaceans which are extremely abundant in polar and boreal seas in the warm months.

The several groups of crustaceans are briefly reviewed below.

WATER FLEAS: Order Cladocera

Water fleas are enclosed in a large, round, bivalve carapace, which does not, however, cover the head, and have two large antennas which are organs of locomotion. *Daphnia* is a fresh-water form commonly sold in pet shops as a living fish food. Some water fleas are very oddly shaped, and all are small, scarcely the size of the head of a pin. Their distribution is world-wide. They are planktonic, very numerous, and an important food for plankton-eating fishes.

OSTRACODS: Order Ostracoda

Like water fleas, ostracods are planktonic, small, swim with the antennas, and are enclosed in a bivalve shell. But ostracods look just like little swimming clams. The study of ostracods is especially important to oil prospectors because certain fossil ostracods are found associated with oil deposits.

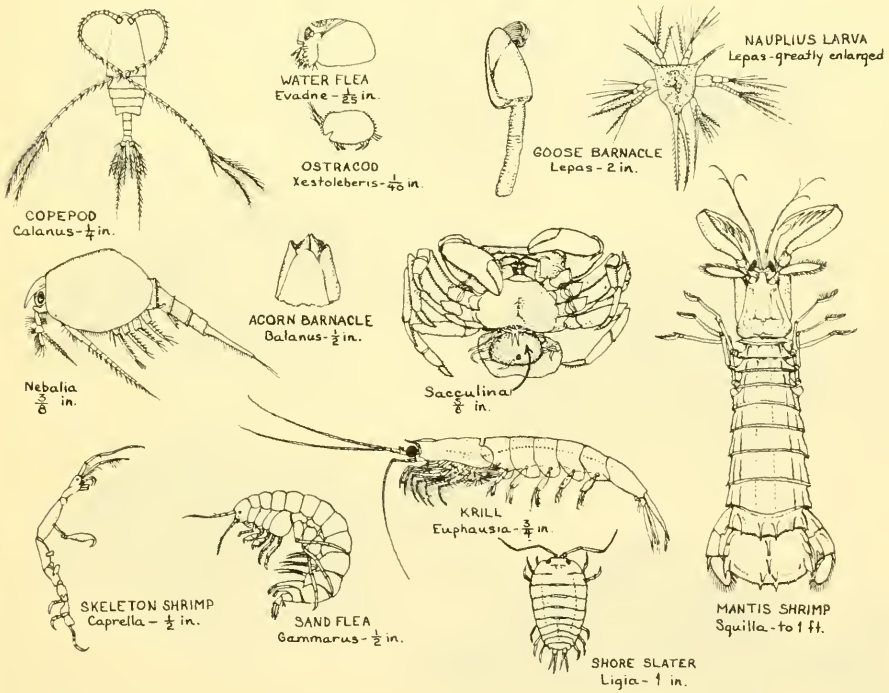


Fig. 37. Lower crustaceans. Adapted from various authors including the Reports of H.M.S. Challenger *(1873–76) and drawn from life.*

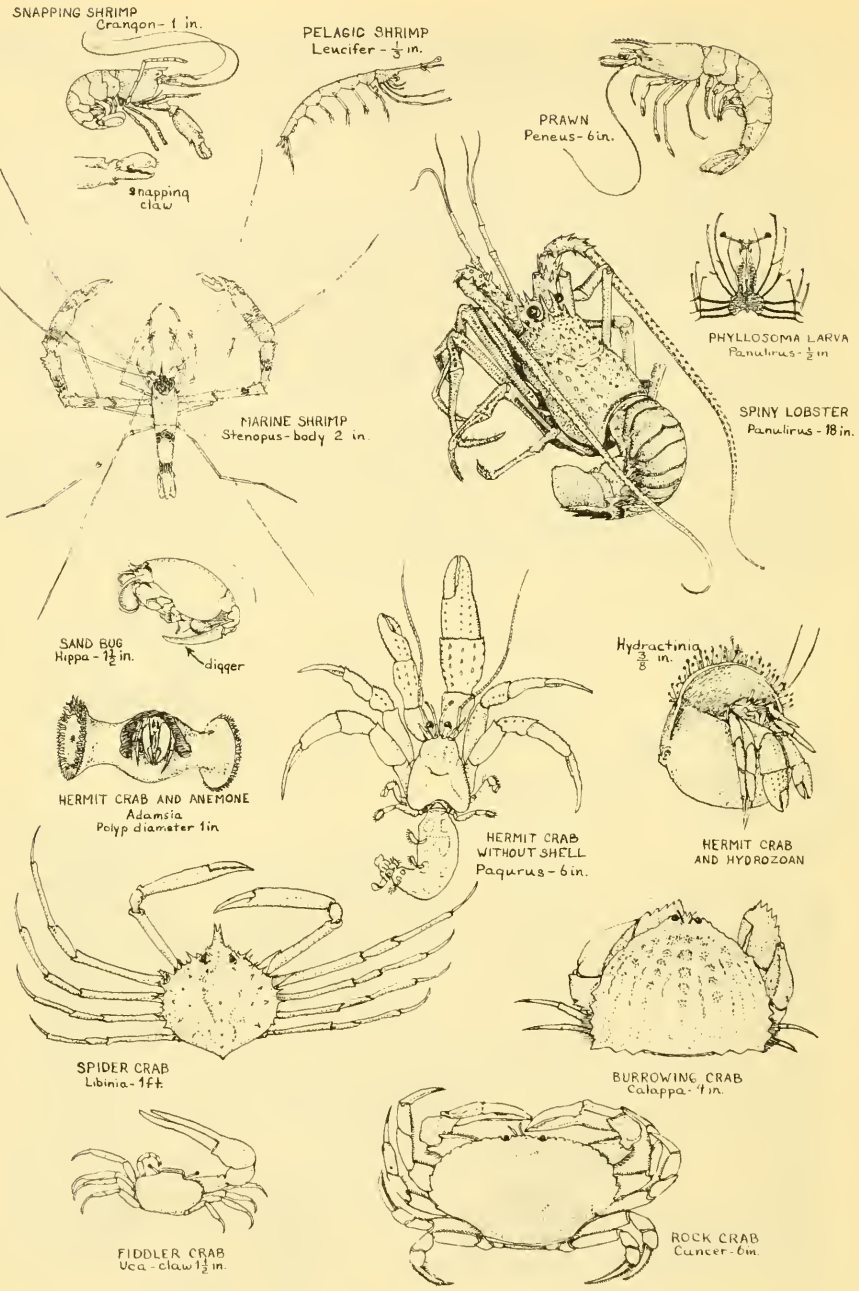
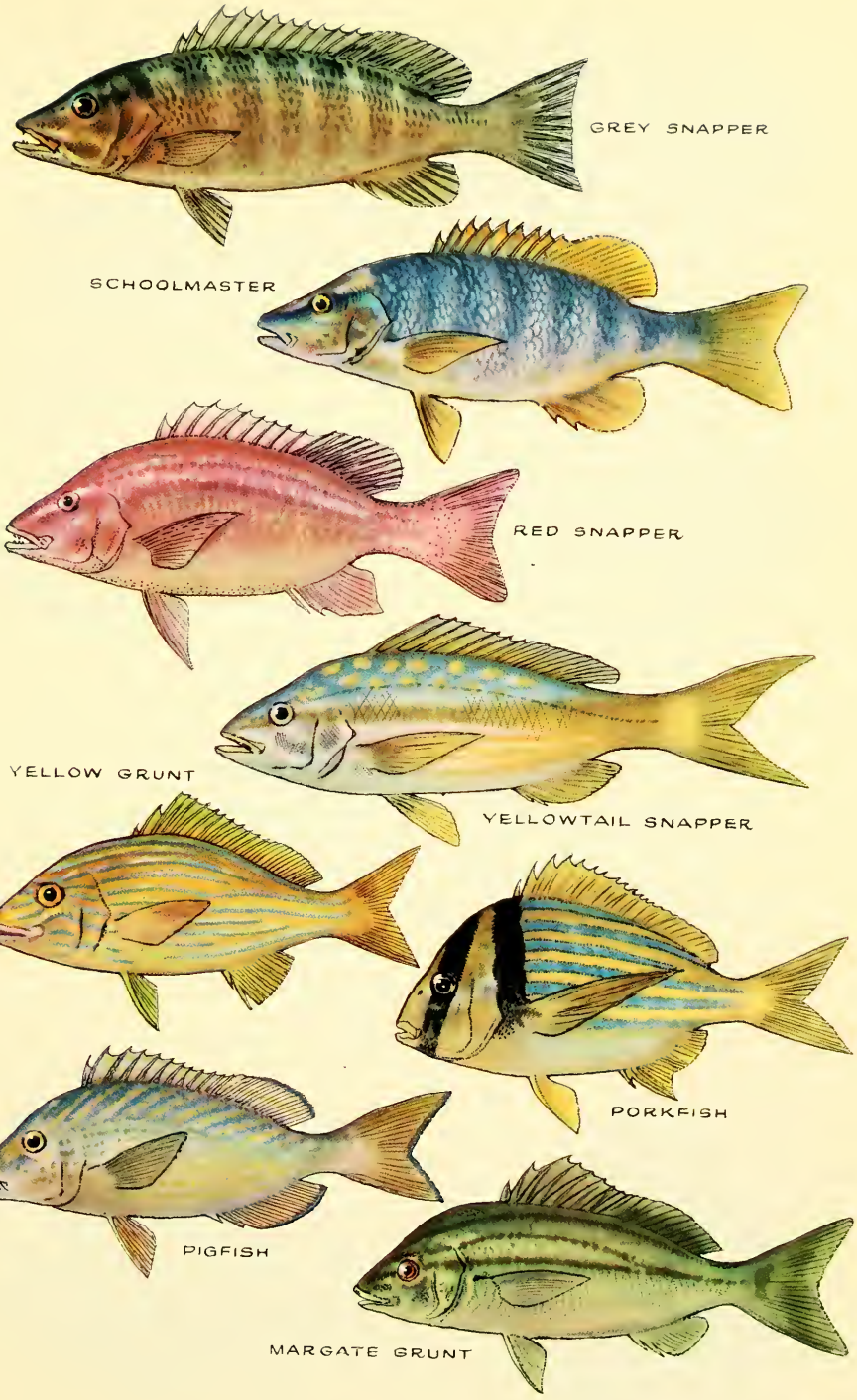
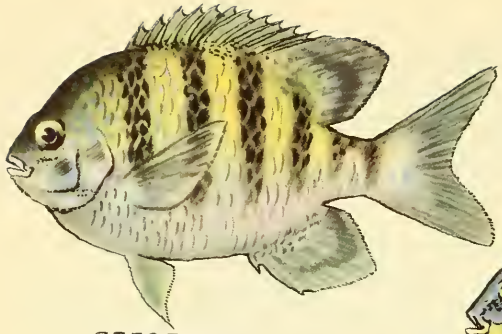


Fig. 38. Advanced crustaceans. Adapted from the Reports of H.M.S. Challenger *(1873–76) and drawn from life.*

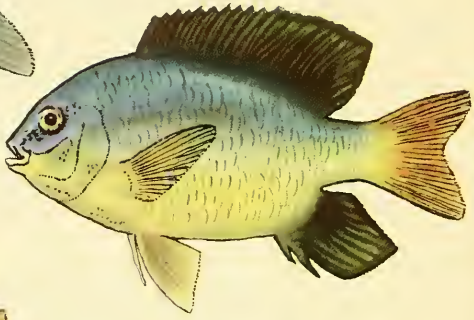


COLOR PLATE 5

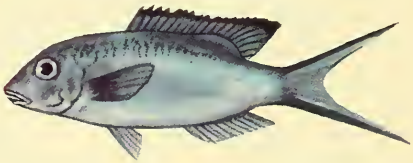


SERGEANT MAJOR

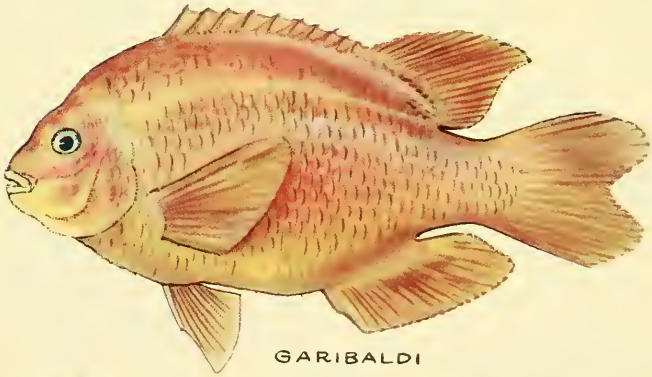
YELLOWTAIL DEMOISELLE



JEWEL FISH

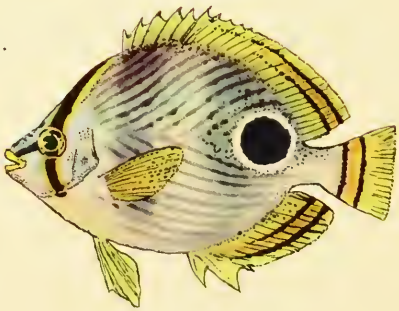


REEF FISH



GARIBALDI

BANDED
BUTTERFLY FISH



FOUR-EYED
BUTTERFLY FISH

COLOR PLATE 6

COPEPODS: Order Copepoda

This is the third and last of the small, planktonic crustacean groups. Again, movement is accomplished by means of two large antennas. Usually there is a single large eye in the center of the head, which has given one fresh-water form the name of *Cyclops,* after the Homeric giant. The body is usually pear-shaped, and the females are often seen carrying two little sacs of eggs attached to their abdomens. *Calanus* is one especially abundant, cosmopolitan copepod which is eaten by fishes and baleen whales. Some copepods are parasitic (fish lice).

BARNACLES: Order Cirripedia

Barnacles have been described as crustaceans that lie on their backs surrounded by a shell, kicking food into their mouths with their feet. These "feet" are actually long appendages that form a sievelike net for the trapping of plankton as they are rapidly thrust in and out of the shell in a grasping motion. Barnacles are the only sessile crustaceans and are hermaphroditic (both sexes in one animal). Hermaphroditism is present in many sessile animals, doubling the number of young produced as the result of one copulation. Sessile animals must produce high numbers of young at a breeding because they can not move from place to place and are thus restricted in acquiring mates. In the case of barnacles the usefulness of hermaphroditism is particularly well illustrated. Unlike many sessile animals which merely shed their eggs and sperm into the sea, barnacles have internal fertilization in which the very long penis of one barnacle deposits sperm directly in the body of a neighboring barnacle. But the barnacle is limited in its mating by the length of the penis, and isolated barnacles out of reach of other barnacles can not mate, although it is possible that these individuals fertilize themselves. The barnacle thus compensates for being sessile by doubling up, each individual being both fertilizer and fertilized, with twice the number of larvae being produced.

The goose barnacles, *Lepas,* attach themselves to substratum by means of a long, muscular stalk. Goose barnacles most often attach to floating objects in the sea, the bottom of ships or to seaweeds. One species attaches to jellyfishes. The acorn barnacle, *Balanus,* is an extremely common animal of the tidal zones of all oceans.

Barnacles frequently attach to living animals such as molluscs, crabs, or lobsters, and one barnacle, the whale barnacle, lives exclusively on whales. Barnacles do not harm the animals on which they attach except by slightly hindering movement, but some specialized barnacles have become parasitic. The most remarkable of these is *Sacculina* (*fig.* 37), a parasite on crabs. The *Sacculina* larva bores through the shell of a crab and pours its cells into the blood of the crab. These cells conglomerate on the underside of the intestine, and then the whole cell mass grows into a rootlike system which permeates the crab's whole body. The part of the *Sacculina* containing the reproductive organs protrudes from the underside of the crab's abdomen. *Sacculina* lives on the body of the crab, but it does not kill the crab, only causing parasitic castration. Eventually, the *Sacculina* drops off, and the crab regenerates its sex organs.

MALACOSTRACANS: Order Malacostraca

The rest of the crustaceans, including crabs, lobsters, sand fleas, shrimp, prawns and others, are included here. In all of them, the appendages on different parts of the body are sharply marked off from each other. The largest appendages are those of the trunk, which are used for locomotion and food-getting and very often bear claws. There are almost always stalked eyes on the head. A carapace covers the head and at least part of the trunk.

All members of this group may be referred in general body plan to a central type, that of the shrimp or prawn, in which the body is adapted mainly for swimming. The species that depart from this general body plan do so as a result of a change of habits to burrowing or crawling, which causes a modification of the limbs on which heavy claws may be developed.

Nebalia, a little crustacean common all over the world on shallow rocky or weedy shores (especially near foul water), is the most primitive of this group. It reaches only a half-inch in length.

The amphipods are elongated and compressed little crustaceans without a true carapace. These are the beach fleas or sand fleas, and there are great numbers of them found literally all over the world, living either semiterrestrially on moist beaches or in shallow water. *Gammarus* is one common genus. The amphipods can swim, walk, and jump. They rarely reach an inch in length, but sometimes they grow larger. The coloration of amphipods often matches that of their background. Except for their movement, they are often difficult to see. Amphipods form a major item of diet for many fishes. One interesting amphipod, the skeleton shrimp, *Caprella,* is about a half-inch long and is often seen clinging to seaweeds, especially *Agardhiella,* or other suitable substrate by means of its small, posteriorly placed legs. It captures small prey with clawed legs near the mouth in a comical-looking, lurching motion of the whole body. Its acrobatics as it clambers over seaweeds are very amusing to watch.

The isopods are small crustaceans that are depressed in body form. The terrestrial sow bugs and pill bugs are examples. Isopods are found on land, in fresh water, over almost all of the sea, and are even sometimes parasitic. Therefore, they qualify as the most widespread of all crustacean groups. Most species are small and found creeping over rocks, in seaweed, or over sand.

The mantis shrimps, *Squilla,* are similar to isopods in being flattened, but they live in burrows in soft bottoms and bear large, raptorial claws, like those of the insect praying mantis, with which they capture prey. Some mantis shrimp reach the large size of almost a foot, but most species are under a third of that size. They are found all over the world.

The rest of the malacostracans are grouped under Eucarida, which includes all the crustaceans in which the carapace covers the whole head and trunk and forms a single unit called the "cephalothorax." Krill, or euphausians, are pelagic, small eucaridans that occur in huge swarms in cold seas and form a basic item of the baleen whale's diet.

The largest of the eucaridans are the decapods, or species with ten legs, which include the crabs, lobsters, shrimps, and prawn. Some decapods are armed with large claws and some are not. Among those that do not have claws is the sand bug, *Hippa,* which lives a rough and tumble life in sandy shores, where it constantly has to battle the force of the breaking surf. The

sand bug filters plankton brought to it by the waves by means of its feathery antennas. The spiny lobster, *Panulirus,* has no claws, but can inflict cuts with the spines that cover its body and antennas. It makes a rasping noise when it is seized by rubbing a knob at the base of the antenna on a rough groove on the face below the eyes.

Very few of the shrimps and prawns have claws. They eat plankton and smaller bits of organic matter. Very often, these animals travel in large schools, and most of them swim actively, whereas the crabs and lobsters walk on the bottom and swim very little. Perhaps the most famous shrimp is the snapping shrimp, *Crangon,* which possesses one huge claw. This claw is used to make a snapping or crackling noise that is well known to divers and which became famous during the last war when it was picked up on underwater sound devices. Schools of snapping shrimp are found in shallow, calm water the world over. The marine shrimp, *Stenopus,* is a very beautiful, clawed shrimp with a white body crossed with blue and red iridescent bands and long, filamentous antennas.

One of the largest and probably the most famous of all crustaceans is the Atlantic lobster *Homarus.* It grows to edible size of 1 to 3 pounds in about five years, but lobsters may reach very old age, a weight of up to 35 pounds and 2 feet in length. *Homarus* is probably the finest-tasting lobster found anywhere.

Some crabs have somewhat reduced the abdomen and must hide this fleshy, poorly protected part in a snail shell which is carried about like a house. These are the hermit crabs, which have some remarkable symbiotic relationships with sponges, hydroids, and anemones.

The true crabs reduce the abdomen to a little tab that folds under the cephalothorax. They form a large and complex group found the world over. Some true crabs have even taken to terrestrial life in the tropics. Crabs are the scavengers of the sea and will eat any organism they can catch or find dead. Their habits are not as varied as might be supposed. They all have large claws which are used for defense and offense or for manipulating objects. The claws of some are to be avoided since they can quite easily crush a finger or a toe. Most crabs display their claws in a threatening gesture whenever they are approached. Some crabs are exceedingly well camouflaged and will not threaten with their claws since they depend on concealment for defense.

Crabs are pugnacious and active animals. Some of the most amusing experiences under water can result from watching their antics, their battles with one another, and their rapid, sidewise scuttlings about for food. One crab that is often seen about coral reefs is the spiderlike arrow crab, *Stenorhynchus* (*fig. 36*). This bizarre and gangling little fellow makes a humorous picture as it reaches out for food with its blue claws and brings the food to a mouth that is far under its long snout.

Arachnids: *Class Arachnida—Figure 39*

This class is mainly a terrestrial one and includes the economically beneficial, but not well-loved spiders, centipedes, and millipedes. The rightfully disliked ticks are also arachnids. Arachnids were among the largest in size and most dominant of marine animals in the Cambrian Period from 400 to 500 million

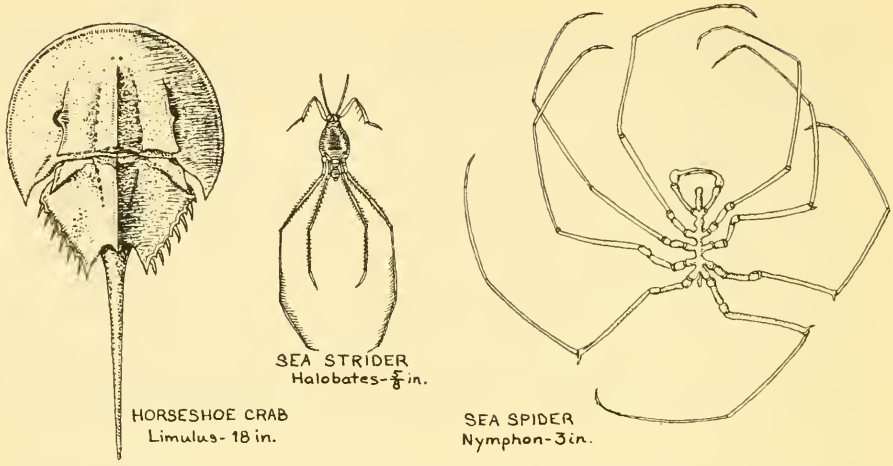


Fig. 39. Arachnids and insects. Adapted from the Reports of H.M.S. Challenger *(1873–76) and drawn from life.*

years ago, before the age of fishes. In Silurian times, 350 million years ago, some scorpionlike arachnids became the first animals to venture onto land. Now, marine arachnids are restricted to a few animals which are either holdovers from the past or have very specialized habits.

The body of arachnids is sharply divided into a cephalothorax (head-body) and an abdomen. There are no antennas and no true mouth parts that could be called jaws, the mouth parts always being of the sucking variety (except for the horseshoe crab).

There are only two arachnid groups in the sea. The first of these contains the living fossil, the horseshoe crab, *Limulus,* which has existed on earth virtually unchanged for almost 200 million years. It is found on sandy shores over much of the earth, especially in the temperate seas of North America and in the western Pacific. Horseshoe crabs are harmless, but the feet of swimmers have accidentally been pierced by the long tail spine. Very large horseshoe crabs may be over 1½ feet long. They crawl slowly over the bottom, grasping invertebrates with their clawed feet. Prey is "chewed" by means of the hard bases of the legs near the mouth. They burrow in soft bottoms and can swim weakly by paddling with their feet. Under the abdomen of the horseshoe crab are a series of leaflike plates. These are the book gills which furnish these animals with oxygen from the water. Commensal flatworms are often found on the leaves of these gills.

The sea spiders or pycnogonids are among the most incredible animals found in nature. They are very often of red coloration since several species live in rather deep water. They range in size from less than an inch in leg span to over 4 or 5 inches. The body is small, and the abdomen almost nonexistent, but the legs are extremely long and contain branches of the stomach which ordinarily would be in the abdomen if the abdomen were large enough. The mouth parts are of a sucking type; sea spiders live by sucking the juices from

such plantlike animals as anemones, sponges, hydroids, and sea squirts, in the same way that some insects such as plant lice (aphids) live by sucking plant juices. Sea spiders are common in all seas, but they are so well camouflaged by their shape and remain so still that they are not very often seen.

Insects: *Class Insecta—Figure 39*

Only one group of insects has invaded the sea, the water striders, familiar bugs which shuttle across calm waters of wooded ponds, lakes, or streams. Oceanic water striders, *Halobates,* are small and tropical in distribution. They are predacious bugs with sucking mouths. They never enter the water but live by walking on it as a land animal walks on the ground. Just how these little insects have adapted to live on the open expanse of ocean where there is no shelter from waves and weather is not well known. They probably feed on small flying insects such as midges that fall on the open sea from the air. They also may eat diatoms.

MOLLUSCS: Phylum Mollusca

The name "Mollusca" refers to the fact that these are soft-bodied animals. Molluscs are nonsegmented, but they have a head with tentacles and usually with eyes. They usually move by crawling about on a foot, a broad flattened area on the ventral surface. In the case of bivalves (clams and oysters) and tooth shells, the foot acts as a digging organ and in the case of cephalopods (squids and octopuses), it is formed into tentacles. The mollusc's outer body covering is called the "mantle" and usually secretes a shell which protects the soft body of the inhabitant.

The molluscs form a gigantic group with about eighty thousand or more species. However, this great array falls rather neatly into five major groups, each of which forms a rather compact unit, both as to form and general habits. In general, molluscs are rather slow-moving, sluggish animals. The exception to this rule occurs in the octopuses and squids, in which the nervous system is among the best developed of all invertebrates.

Chitons: *Class Amphineura—Figure 40*

These are the most primitive of molluscs. The body is shaped like an oval disc and always bears eight hard plates on the back for protection. There are no tentacles. Some rather rare or deep-water chitons are wormlike in shape, but the great majority adhere closely to the body plan described. They are all animals of shallow, rocky shores where they adhere with their muscular foot, often so tightly that they cannot be removed without breaking them. Chitons browse on algae, using their tongues, which bear hard rasping teeth called a "radula," to scrape their food from rocks. By day, chitons prefer to rest in shady crannies or dark places on the undersides of rocks, but they wander about freely at night. Chitons defend themselves by rolling into a ball like an armadillo or pill bug.

Chitons are found in all waters in the world. They are mostly under 3 inches

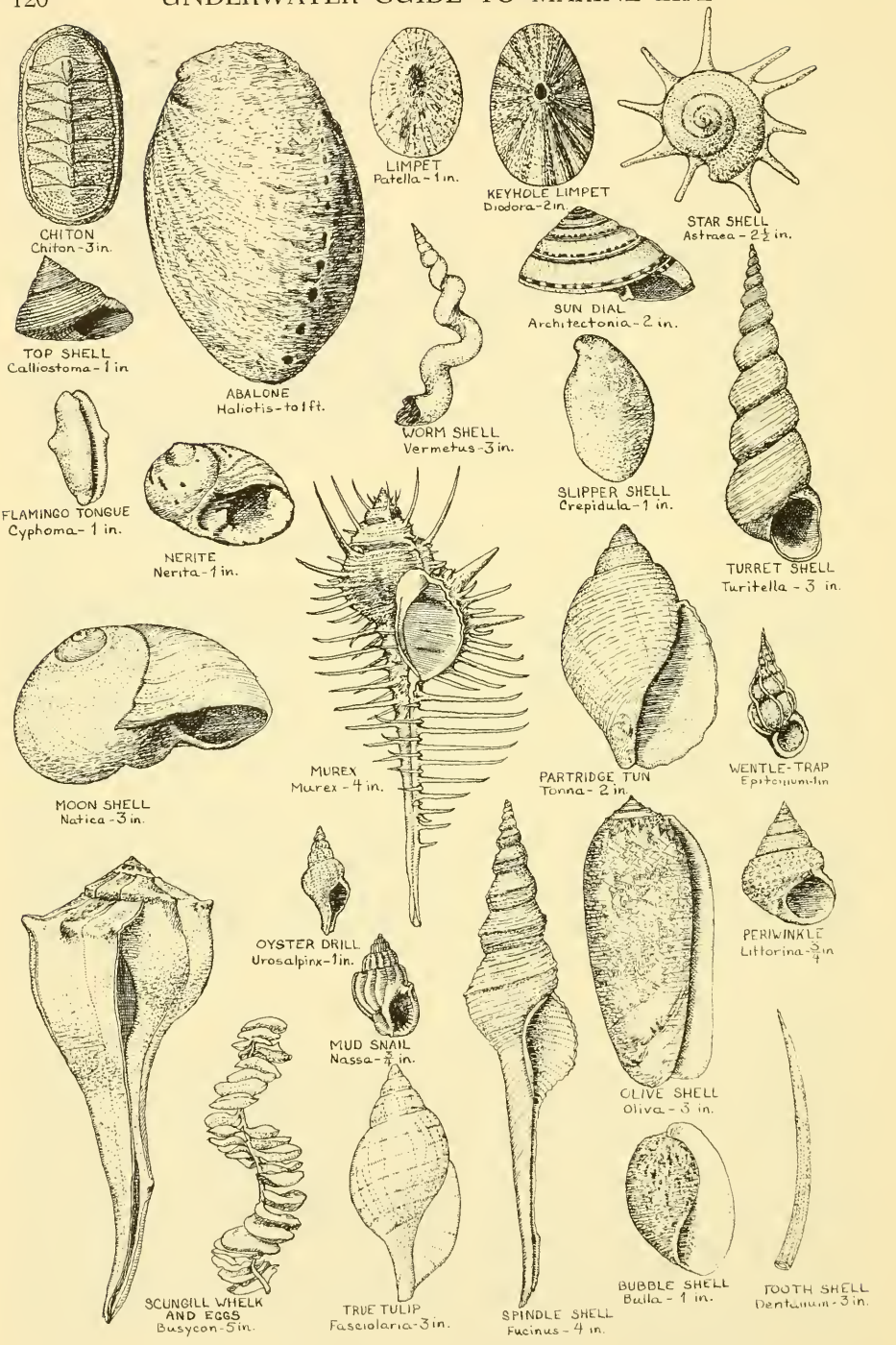


Fig. 40. Chitons, snails, and tooth shells. Drawn from life. See also Color Plate 10.

in length, but the Pacific *Cryptochiton* reaches almost a foot. There are many species off the Pacific Coast of North America. Chitons are less numerous in the Atlantic.

Snails: *Class Gastropoda—Figure 40*

This is the largest class of molluscs by far. The body is short and is usually covered by a single, spiral shell. Locomotion is accomplished by means of the flat, muscular foot upon which the animal glides. Some conchs use the foot to make short jumps rather than as a glider, and the small, planktonic pteropods have 2 winglike feet for swimming at the surface of the sea.

All snails have tentacles bearing chemoreceptors and eyes. None of them move rapidly. The mouth has a tongue with a radula. The beautiful shells of snails have caught the attention of collectors.

The most primitive of gastropods are the flattened limpets, keyhole limpets, and abalones. These are all animals of tidal or subtidal rocky shores. All scrape algae from rocks with their many-toothed radula or eat dead organic matter, and all are more active by night than by day. The limpets and keyhole limpets are the smallest, never reaching over 4 inches and averaging much smaller. The abalones, however, reach a foot in length and are delicious as food. They are found only in the Pacific and are treated as game animals protected by law on the Pacific Coast of the United States. The limpet, in spite of the primitive nature of its nervous system, shows a remarkable homing behavior. Each limpet has a definite place on a rock to which it adheres when it is uncovered at low tide. It wears a depression in the rock which conforms to the shape of its shell. When covered by water at high tide, the limpet moves away as much as three feet from its rock, "scar" home to browse, returning again at low tide. It finds its way back by remembering the topography of its home rock and always fits itself into the scar.

The rachiglossans are snails that have only three large teeth in the radula. These are used to bore through the shells of clams and oysters or other molluscs or perhaps other animals. All of them are carnivorous. The well-known whelk (scungill), *Busycon,* is a large species which lays eggs that look like a string of flattened beads. The oyster drills, *Urosalpinx,* are pests in oyster beds. *Murex* (*Color Plate 10*) is a widespread tropical genus which has a shell that is distinctly laminated and often very spiny at the places where the lamellae overlap. *Nassa* is a small species that eats other molluscs but also scavenges; it is very common on mud bottom.

The taenioglossans make up the great majority of snails. They include carnivorous species such as the moon shell, *Natica,* which feeds on shellfish and lays eggs in sand collars, common objects cast up on beaches. The slipper shells, *Crepidula,* and periwinkles, *Littorina,* are common tidal or subtidal vegetarians of rocky shores. The queen conch, *Strombus gigas* (*Color Plate 10*), forms a home for the little conchfish and is among the largest of snails, often weighing over 5 pounds. It progresses by jumping and is a scavenger. The cowries, *Cypraea* (*Color Plate 10*), are among the most beautiful and most sought after of shells. They are most common in the tropics and not very abundant in North America. The helmet shells, *Cassis,* include the king conch

or king helmet (*Color Plate 10*). Helmets prey chiefly on bivalve molluscs and reach a size almost as large as that of the queen conch.

The toxoglossans include the poisonous cone shells, *Conus* (*Color Plate 10*), which have the radula reduced to two long, sharp lancets attached to a poison gland. The cone shells are not known to be dangerous in North America, but some of the South Pacific species are deadly. They should not be handled. Treatment of the poisoning is just like that for snakebite (consisting of lancing the wound in order to encourage bleeding, followed by immediate attention by a physician). Cone shells can always be recognized by their conical shape.

The remaining groups of snails all tend to reduce the shell. Pteropods are seldom more than ¼ of an inch long, have transparent, papery shells, and are planktonic. Their foot is divided into two large "wings" for purposes of swimming. They are common enough in some places to form bottom oozes from their cast-off shells. The large sea slug or sea hare, *Aplysia* (*color photograph*), reaches almost the size of a football, feeds on algae, and ejects a harmless, inky fluid when it is molested. The smaller plumed sea slugs or nudibranchs (*Color Plate 10*) are probably the most beautifully colored of all invertebrates. Their soft but iridescent colors and flowing movement are extremely beautiful. They grow to a maximum of about 4 inches. Most plumed sea slugs are of cold-water distribution, but some species are also found in the tropics. They are carnivorous, and some are almost unique in that they eat sponges which are avoided by all other animals but sea spiders. Other species eat anemones or bite the heads off hydroids for food. (The hydroids do not seem to be bothered much by this since they quickly grow a new head.) The plumes on the backs of sea slugs are used as respiratory gills and have given these animals the name of "nudibranch" which means "naked gills." One nudibranch, *Eolis* (*Color Plate 10*), has extensions of its digestive tract reaching up into its dorsal plumes. The nematocysts of the coelenterates, which it eats, are stored in these extensions and are used by *Eolis* for defense—a completely unique use of the defensive mechanism of one animal by another. *Eolis's* plumes are brightly and warningly colored, and *Eolis* is avoided by fishes.

Tooth Shells: *Class Scaphopoda—Figure 40*

These little animals have a long hollow shell, a radula like the snails, and a burrowing foot like the clams. They never are more than about a half-foot long and are usually half that length. They burrow into sandy or muddy bottoms and feed on microscopic organisms. They are chiefly of cold or deep waters offshore.

Bivalves: *Class Pelecypoda—Figure 41*

These are compressed animals with no head and with two shells or valves united by a hinge. The hinge is elastic, and when the shells are closed by muscles, the hinge is compressed. When the muscles are released, the hinge causes the shells to open. Thus, these animals must exert muscular force to keep their shells closed but exert no force to open them. A starfish is able to tire a bivalve merely by a continued pulling force. When the much stronger bivalve relaxes its muscles out of exhaustion, the starfish is able to eat it.

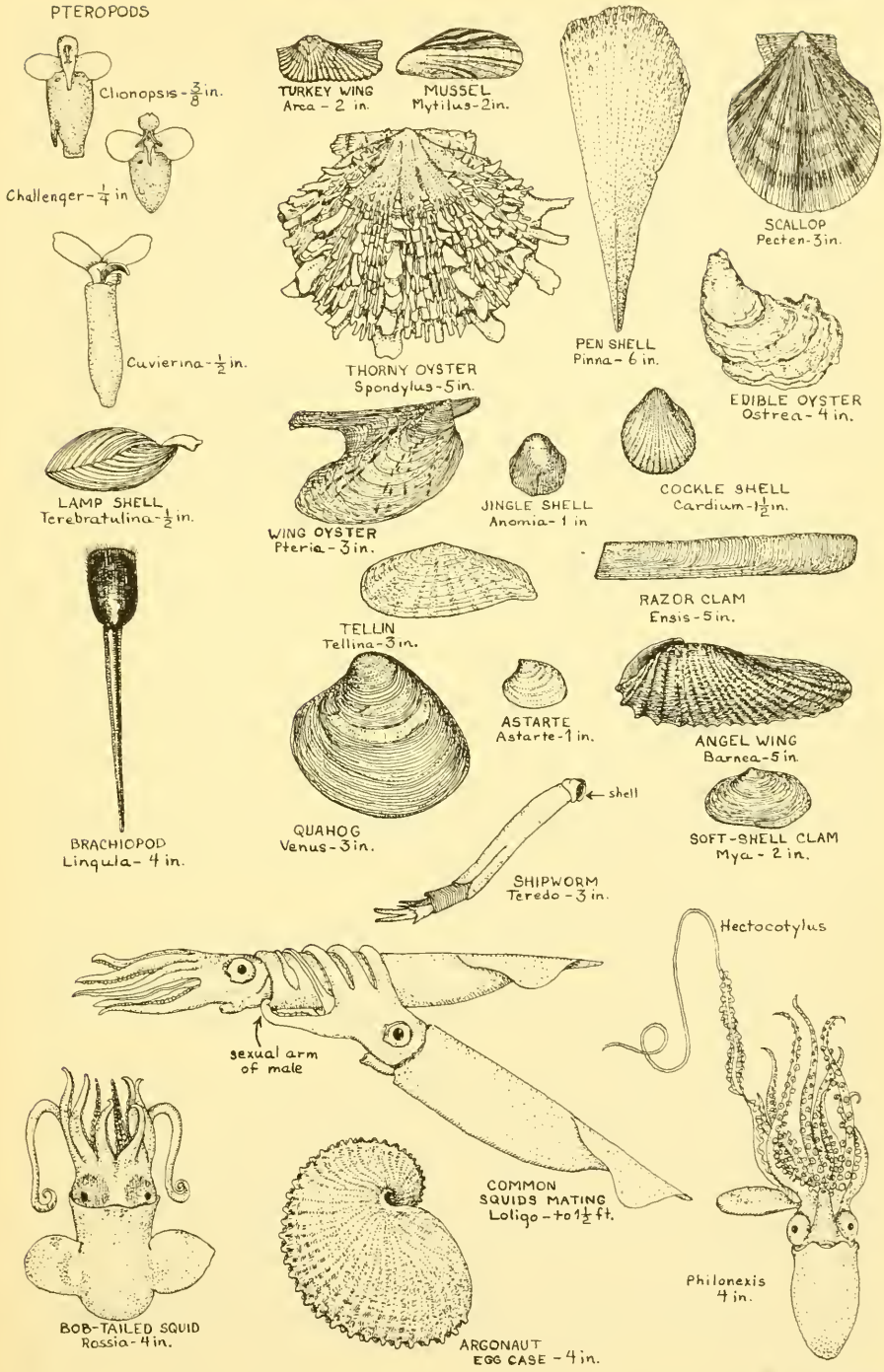


Fig. 41. Clams, pteropods, cephalopods and brachiopods. Adapted from the Reports of H.M.S. Challenger *(1873–76) and McGowan (1954) and drawn from life.*

Bivalves are adapted mainly for protection. Their thick shells are so effective in this respect that this ancient group has evolved very little during the many million years of its existence. It is true that about all they do is feed and breed and secrete a shell. In general, they move only a little, their major response to disturbing stimuli being a closing of the shells.

Almost all bivalves are filter-feeders. They have incurrent and excurrent siphons through which sea water enters and leaves the body. This water brings oxygen and microscopic, planktonic nutrients to the bivalve. The bivalves form a very compact group. Some, such as the mussel, *Mytilus,* are sessile and attach themselves to hard substrate by means of tough threads called a "byssus." The jingle shells, *Anomia,* have fragile shells and are common in all seas attached to all sorts of solid objects in shallow water. The ark shells, *Arca,* have heavy shells, and one species, the bloody clam, *Arca pexata,* is the only mollusc with red blood. Oysters, *Ostrea,* are also attached to solid substrate. They have the capability of changing from one sex to the other alternately. A few species of oysters form commercially valuable pearls. Pen shells, *Pinna,* are common, thin-shelled, tropical species which have a sharply triangular shape. They frequently are seen partly buried, pointed end down, in sand. The upper end is very sharp and can inflict deep cuts.

Among the nonattached and motile pelecypods are the quahog or cherrystone clams, *Venus,* which are typical of the many burrowing clams of sandy or gravelly beaches. The soft-shelled clams, *Mya,* have a thinner shell than the quahog and prefer softer bottoms like soft sand or mud. The same is true of the angel-wing clam, *Barnea,* and the razor clam, *Ensis,* which also have fairly delicate shells. Clams with thin shells have, in general, longer syphons and bury themselves deeper than do the harder-shelled species. They are also more active and faster diggers than the hard-shells.

One species of pelecypods has left the general protectively shelled pattern of adaptation described in previous species. The shipworm, *Teredo,* is actually an almost naked clam that uses its reduced shell to bore through wood. Like termites, shipworms utilize wood for food.

The scallops, *Pecten,* are actively swimming pelecypods. They clap their shells vigorously together to force water out of the body cavity and thus move by a sort of jerky jet propulsion. Scallops have photoreceptors around the edge of the mantle and also have long, sensitive tactile and chemoreceptive tentacles attached to the mantle's edges.

All clams and oysters are edible, and some are delicious, but because of their filter-feeding habits, they may at certain times of the year and in some waters become poisonous. Obviously, pelecypods from foul or polluted waters should be avoided. In the summer, toxic bacteria and protozoans may become plentiful enough in some waters to cause pelecypods, with these microorganisms in their digestive tracts, to become poisonous. It is also said that during the breeding season some clams and oysters are toxic due to the accumulation of sex products in them. At any time of year, these animals spoil quickly. They should be eaten only when absolutely fresh. It is generally a good rule to eat pelecypods only during months which have an "r" in them; the cooler months, September through April.

Squids and Octopuses: *Class Cephalopoda* (*"head foot"*)—*Figure 41*

In this group, there is a definite tendency to lose the shell and to become active and predatory. Some cuttle fishes, *Sepia,* still have a shell known as "cuttlebone," but it is entirely internal. The common squids, *Loligo,* have a fragile pen-shaped shell buried in their flesh and the octopuses are without shells. In all cephalopods the foot is developed into a circlet of tentacles around the mouth. The mouth has a parrotlike beak, and the bites of cephalopods are poisonous, sometimes dangerously so. Although these animals are not often inclined to bite, their means of defense centered elsewhere, they should be handled only with care. While the tentacles are not dangerous, the bites from octopuses have been known to result in death.

Defense consists of protective coloration coupled, in the case of octopuses, with secretive habits or, in the case of squids, with speed of swimming. When molested, all cephalopods have the habit of emitting a smoke screen of dark inky fluid and then making a hasty retreat. In some deep sea squids, the ink is luminescent.

Cephalopods are the largest, speediest, and most active of invertebrates. The giant squid, *Architeuthis,* is a favorite food of the sperm whale, lives in the deep sea, and reaches a length of about 50 feet including the long tentacles. Some octopuses have an armspread of over 12 feet. Octopuses are shy animals, but large ones are less shy than small ones.

The nervous system of cephalopods is extremely well developed. Their giant nerve fibers conduct nervous impulses at a very rapid rate. Their eyes are very much like mammalian eyes, and these animals see very well. These features provide cephalopods with the extremely fast reflexes necessary for active predatory animals, but they do not necessarily imply intelligence, for which integration of senses and actions is needed (Chapter 2). In fact, the intelligence of these animals, like their ferocity, is often overestimated.

Cephalopods are the original inventors of jet propulsion. They draw water into the mantle cavity and forcibly eject it from a siphon. They can change direction by moving the siphon, but they usually swim backwards.

The color changes of cephalopods are the most rapid and striking to be seen in the entire animal kingdom. By means of rapidly redistributing pigments in their pigment-bearing cells or chromatophores, they can cause complete change of color or even waves of color to pass over their bodies in a matter of seconds. Most cephalopods match background by means of color change. They also change colors when feeding or in response to stimuli leading to fear.

The tentacles of cephalopods are organs used for food-catching, movement (octopuses crawl), and reproduction. These tentacles bear suckers, the power of which is remarkable. Even a small octopus of only a few feet in tentacle spread can hold onto a rock so as to be almost immovable. Care should be taken by the diver not to let an octopus grasp him and a rock at the same time. This the octopus will not do as an aggressive action, but only if it is first molested.

During copulation, sperm is transferred to female cephalopods with one specialized tentacle which usually has the suckers reduced in number and size. In some octopuses, namely the paper argonaut, *Argonauta,* and *Philonexis,* the

sperm-bearing arm is actually detached from the male and placed in the mantle cavity of the female. This arm was originally thought to be a separate animal, a worm, and was named *Hectocotylus*. Most octopuses do not lose their sexual arms during copulation, however.

Cephalopods can be divided into two groups on the basis of how many arms they have. The squids have ten arms, two of which are much longer than the rest. These are very swift-swimming animals which are common near shore or at sea the world over. They eat fishes and invertebrates. The common squid, *Loligo*, is a common shore form and reaches a length of 1½ feet. *Sepioteuthis* (*color photograph*) is found in the West Indies and is very beautifully colored. Both of these show preference for traveling in schools in precise military formation. Sometimes as many as several dozen may be seen lined up swimming together.

The octopuses have eight tentacles, usually all of equal length, and are of bottom-living habits, eating other invertebrates such as molluscs and crustaceans mostly. Some are small and pelagic and fairly good swimmers. Others are extremely flattened and sluggish, spending most of their time attached to rocks. But most are shy and nocturnal, though active, bottom animals. Klingel (1944) gives a sympathetic account of the common octopus, *Octopus* (*Color Plate 10*). He says that the best way to spot the home of one of these shy animals is to take note of the presence of a pile of shells and stones which the octopus accumulates near its home. After feeding, the octopus has the peculiar habit of drawing hard objects to its body.

Octopuses show fear by means of a livid white color phase, but they also have color phases composed of virtually every shade or pattern imaginable. Ink is used both for a defensive smoke screen and for recognition of one octopus by another at night. The paper argonaut, *Argonauta*, is an octopus, the female of which forms a beautiful papery shell as an egg case. The argonaut is an animal of rather deep tropical waters, but it appears at the surface when it is breeding.

BRACHIOPODS: Phylum Brachiopoda—*Figure 41*

This phylum is mentioned chiefly because one species holds the geological longevity record for all animals; *Lingula* has been in existence for 400 million years. Brachiopods are not now very varied, but were among the most common of animals many million years ago. They look like bivalve molluscs since they have two shells and filter-feed on plankton, but they are actually quite different anatomically. The lamp shells are brachiopods that grow attached to rocks by a stalk. Brachiopods are fairly common in deep water offshore, but a few are found in shallow waters.

ECHINODERMS: Phylum Echinodermata (*"spiny-skinned"*)

The starfishes and their allies form an important group evolutionarily speaking since they have a larva that looks very much like the larva of some prochordates. Therefore, the chordates (including vertebrates) and the echinoderms are thought to have common ancestry.

Adult echinoderms are characterized by the tube feet by means of which

they move. These are little tubes that have suction discs at their ends and which operate by means of an internal bulb that pumps water into the muscular foot, causing it to expand, and that sucks water from the foot, causing it to contract. The strength of several hundred feet working together is considerable. There are five groups of these spiny-skinned animals.

Starfishes: *Class Asterida—Figure 42*

As the name implies, these are star-shaped animals. They are especially diverse on the west coast of North America where the sun star, with a diameter of up to 2½ feet, is the largest starfish known. All starfishes are carnivorous on bivalve molluscs. They settle over a bivalve and exert a steady pull on the bivalve's shells. Eventually, the bivalve tires, and the starfish then extends its stomach into the bivalve and digests the bivalve right in its shell. Starfishes are not very variable in form. (The very common large West Indian star, *Oreaster*, is shown in figure 43.) Some starfishes are blue, and others are red, brown, or even bright yellow. All can regenerate arms if these are lost.

Brittle Stars: *Class Ophiurida—Figure 42*

These are the most active of the echinoderms, able to move quite rapidly with their long serpentlike arms. In fact, they are often called "serpent stars." They are fragile and may even purposefully break arms off when they are handled, a defense mechanism that occupies the predator's attention while the brittle star makes its escape. In the middle of the underside of the body is a mouth with serrate, toothlike edges. These are used to sift out and chew the small pieces of organic matter on which these animals feed. Most species are nocturnal, and some are very common in deep water. (A typical brittle star is shown in Color Plate 10.)

The basket star or Gorgon's head, *Gorgoncephalus*, is an extraordinary and very sluggish brittle star that has finely branched arms. It is common in the tropics and reaches a width of 2 feet, but because of its sedentary habits and protective seaweedlike shape, it often goes unnoticed. It may be found adhering to corals or clumped in the branches of sea plume gorgonians, where it catches small, planktonic animals with its tentaclelike arms.

Sea Urchins and Sand Dollars: *Class Echinida—Figure 42*

The bodies of these animals are rounded and spiny in the case of sea urchins and flattened and smooth in the case of sand dollars. There is a shell formed of calcareous plates and on the underside is a five-toothed chewing apparatus called "Aristotle's lantern" with which these animals scrape their algae food from hard surfaces or chew organic matter. These animals move slowly by means of tube feet and depend on their spines or hard shells for protection, for their meat is tasty, forming an excellent chum for fishes. Sea urchins and sand dollars range in all waters of the world over all types of bottom. The long spines of the needle-spined sea urchins, *Diadema*, common in all warm seas, are very sharp and brittle and easily pierce flesh, gloves, or even shoes. The spines break

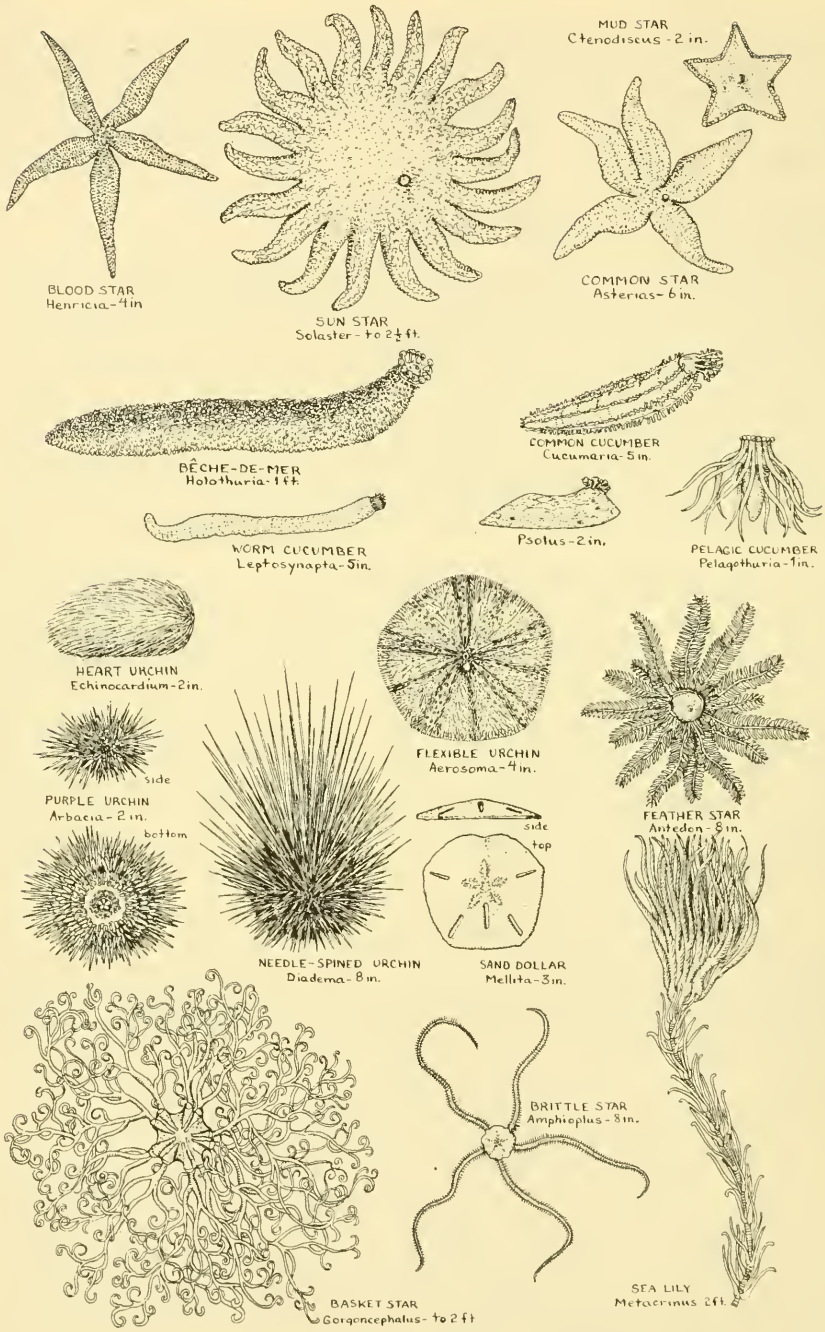
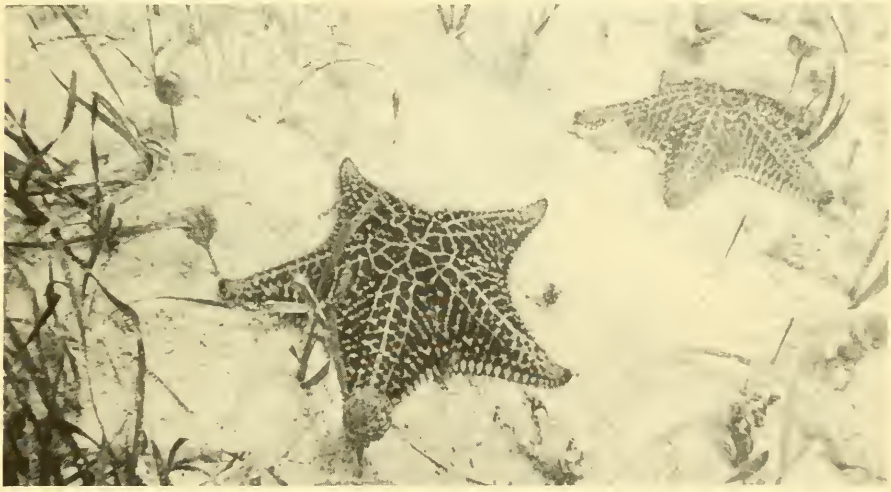


Fig. 42. Echinoderms. Drawn from life.

Fig. 43. Top. The bèche-de-mer, Holothuria, *averaging about eight inches, is an extremely sluggish mud-eater. The pearlfish uses the bèche-de-mer's cloaca for a home (photograph courtesy John A. Moore). Bottom. The West Indian star,* Oreaster, *is commonly found on sandy, weedy bottom among plants like turtle grass,* Thalassia, *and the alga, the merman's shaving brush,* Penicillus.



off in the flesh and liberate a purplish fluid which stains the wound. The sensation is painful, but the effects are not generally long-lasting. The bits of spine that cannot be pulled out soon dissolve in the flesh. Most sea urchins do not bear such sharp, long spines, but sharp-spined species should not be handled barehanded. Some that have short spines have poison glands associated with these spines. These are the flexible urchins, one of which, *Aerosoma,* has a sting reported by Phillips and Brady (1953) to be as painful as that of the Portuguese man-of-war. Luckily, this urchin keeps to rather deep water.

Sea Lilies: *Class Crinida—Figure 42*

These are almost exclusively deep-water animals and are among the most common of animals found there. Deep-water sea lilies are stalked and very plantlike. There are a few sea lilies that break off their stalks and swim by waving their arms. One of these is the sea feather or feather star, *Antedon,* and it sometimes ranges to waters only about 100 feet deep. It is of temperate distribution.

Sea Cucumbers: *Class Holothurida—Figure 42*

The only echinoderms that have lost their spiny or hard skin are the sea cucumbers, which have an appearance exactly like their name. They exist in shallow and deep waters all over the world and may be either chunky and muscular or elongate and delicate. A ring of tentacles encircles the mouth. The tentacles are tactile and chemoreceptive organs. Tentacles also serve to shovel mud and sand, the sea cucumber's source of food, into the mouth. Some sea cucumbers have the defense mechanism of eviscerating themselves through the mouth by means of a violent contraction of the body when they are disturbed. The sea cucumber soon regenerates the internal organs. The bêche-de-mer, *Holothuria* (*fig. 43*), is a common form found in tropical seas the world over. (Its commensal relationship with the pearlfish is described in Chapter 10 under that fish.)

INVERTEBRATE CHORDATES: Phylum Chordata

This is the phylum to which the vertebrates belong, but there are some invertebrate members of this phylum. These invertebrates are the species that have no backbone, hence are truly invertebrates. But they do have other internal, anatomical characters that vertebrates have (including a dorsal, tubular nervous system), and these place the invertebrate chordates or prochordates in the same phylum as vertebrates. All of the prochordates are filter-feeders, and most of them are small.

Cephalochordates: *Class Cephalochordata—Figure 44*

These are the lowest forms of fishlike animals. *Amphioxus* and its close allies are small, up to 3 inches or so, and are common buried in clean, sandy shores of much of the world. They lie in the sand with the mouth protruding, filtering plankton from sea water by means of a large basketlike pharynx.

Hemichordates: *Class Hemichordata—Figure 44*

The acorn worms, *Balanoglossus,* and others, live in holes in soft-bottomed shores and feed, as do other prochordates, by filtering sea water. The acornlike "head," which is used both in burrowing and feeding, separates them from other wormlike animals. Some members of this class are small, sessile, and colonial. They live on the sea bottom and are not likely to be encountered by the diver.

Tunicates: ***Class Tunicata—Figure 44***

The sea squirts are the most common prochordates and are most likely to be encountered. They are little, round, or elongate, vaselike animals that have two openings, an incurrent opening for taking in water, and an excurrent one for passing water out. Thus, they resemble clams in this respect and filter-feed exactly as clams do. *Ciona* and *Molgula* are two common, shallow-water sea squirts that live attached in groups to rocks or pilings in shallow water. The name "sea squirt" is derived from the habit that these animals have of squirting water when they are handled.

There are several almost transparent members of this class that might be mistaken for comb jellyfish. Like comb jellyfish, they are pelagic and swarm on the open sea. Some of them are solitary and others are colonial and all are filter feeders. *Salpa* is one solitary form of fairly large size. *Pyrosoma* lives in the tropics, is colonial, and has living in it a luminescent bacteria. Large masses of *Pyrosoma,* when stimulated, emit light strong enough to read by. Young (1950) reports that this light may be a protective device since fishes that seize these animals drop them when their lights go on.

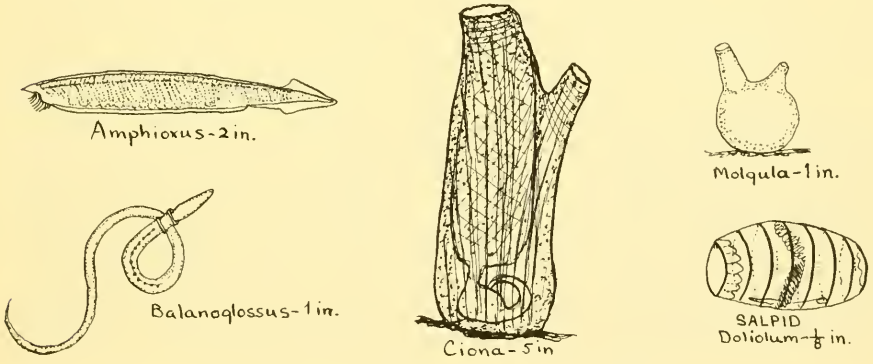


Fig. 44. Prochordates. Drawn from life.

SECTION THREE

Animals with Backbones: The Vertebrates

CHAPTER 8

THE LOWER FISHES—Lampreys, Sharks, Rays, and Ratfishes

The vertebrates—fishes, amphibians, reptiles, birds, and mammals—compose the dominant and most advanced of the chordates (Chapter 7). This is an extremely diverse group, united by the possession of at least traces of a backbone composed of separate vertebrae. They also possess a cranium which encloses and protects the specialized anterior end of the central nerve chord, the brain. It is through the specialization of the brain and the allied sense organs (eyes, nose, ears, etc.) that the advanced vertebrates are able to respond more delicately to subtle modifications of their environment than any other animals. Thus they have become the dominant living organisms on the earth and in the sea. It is not at all clear where the vertebrates came from. Probably some of the prochordates had common ancestors with some vertebrates, but this occurred so long ago (at least 500 million years) that the story is not preserved in fossil form for us to interpret today.

THE JAWLESS VERTEBRATES: Class Agnatha (*"without jaws"*)

This group, widespread in the temperate zones of both hemispheres, includes descendants of a once prominent array of fishes called "ostracoderms" which lived over 300 million years ago. The ancient forms were mud-eating, bottom-living marine animals which looked more conventionally fishlike than their eellike descendants, the lampreys and hagfishes of today. These have survived probably because they took up a very specialized mode of life—parasitism. It is a matter of definition whether to call the lampreys and hagfishes "parasites," "carnivores," or "scavengers." Theoretically, the parasitic habit begins with a stage in which an animal merely partakes of part of the living host's tissues but lives a largely independent life. The mosquito is an example. Gradually, as evolution progresses, the dependence on the host increases until the parasite is virtually completely dependent on the host. Such is the case with the tapeworm. Lampreys and hagfishes are a borderline case. They are specialized in feeding

methods but are not so host-dependent as to have become nearly as anatomically altered as the tapeworm. Some biologists prefer that they be called "specialized carnivores," but since they feed on living prey, the term "parasite" is better. As is so often the case with parasites, the body form has tended to become simple and degenerate, in this case elongate and with a poorly developed skeleton of cartilage. The hagfishes tend to be scavengers, too, since they feed on dead or dying prey.

The Agnatha are distinct from all succeeding vertebrates because of their lack of paired fins and jaws. In the modern forms the mouth is merely a round disc with a hole in the middle containing a rasping tongue. This mouth acts as a powerful sucking mechanism. Hence, these forms are sometimes called the "Cyclostomata" ("round mouth"). With this mouth they are able to do such things as grasp and bore into their fish prey, build a nest of stones, anchor themselves to rocks, pilings, or even boats, and grasp their mates while breeding.

Because of the lack of paired fins, they are not very good swimmers. Though they can dash for prey at considerable speed, their steering is not as good as that of fish with more fins and shorter bodies. One does not see them swimming about nearly as much as one sees them attached to some item of substrate waiting to strike, almost snakelike, at some unlucky fish that happens to pass their way.

The two groups of agnathans are distinct, and each attacks its prey in a quite different way.

LAMPREYS: Family Petromyzontidae

There are usually seven gill openings on each side, and there are no barbels on the snout. The eyes are large, and the dorsal fin is discontinuous. Lampreys swim vigorously but not too efficiently, and are active, voracious animals. They attach themselves to fishes, preferably at the softer throat, side, and belly regions, and scrape away the skin with the rasping tongue in order to suck the blood and eat some of the flesh. Their saliva is an anticoagulant. Very often this either kills the prey outright or so weakens it as to cause delayed death. Larger fishes do recover. They prefer the soft-scaled fishes. Hard scales seem to be protection against attack.

Not much is known of lampreys in the sea, though they spend most of their lives there. They are most commonly observed in streams in the spring, where they go to breed after a certain unknown number of maturing years in the sea. In this respect, they are like salmon and are said to be anadromous. During their journeys up rivers, they perform remarkable acrobatics in climbing rapids and low falls with the aid of their sucking mouths. In the riffles, a nest is scooped out of gravel and large numbers of small eggs are laid. These hatch into *Ammocoetes* larvae which are nonparasitic but look much like the adults. After spending three to five years in fresh water, having attained a 6-inch length, the *Ammocoetes* go to the sea to mature, and the breeding cycle begins again.

Lampreys may become landlocked as they have in the Great Lakes, where they have all but destroyed the lake trout and whitefish industries. In spite of a repulsive appearance, they are edible and quite tasty. Formerly they were a popular food in New England and in Europe.

Lampreys are found in all temperate seas.

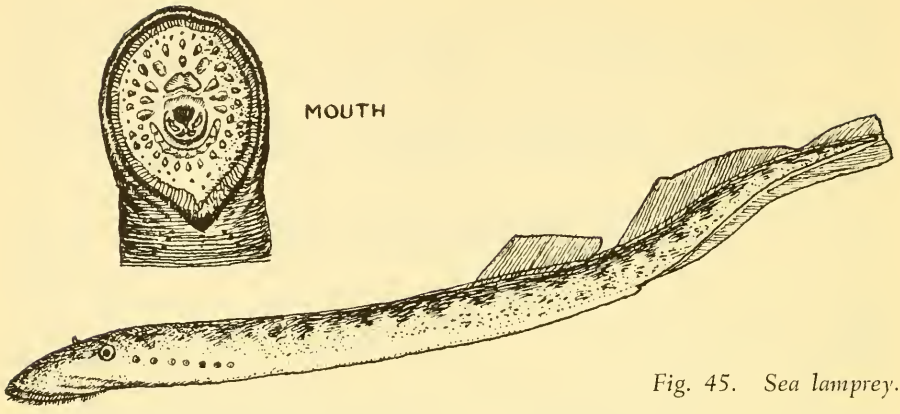


Fig. 45. Sea lamprey.

SEA LAMPREY: *Petromyzon marinus*

Size: Up to 3 feet.

Weight: Up to 3 pounds.

Distribution: The North Atlantic of Europe and the United States south to Chesapeake Bay and rarely to Florida.

Identification: Same as for the family.

Habits: This lamprey is known to attack members of the cod and mackerel families. Probably it also preys on other soft-scaled fish. Fish are sometimes caught by fishermen which bear the scars of such attack. They have not been recorded attacking warm-blooded prey such as man, but if one does attach to an arm or a leg, so strong is the grip, it cannot be pulled off. However, raising the animal out of the water will cause it to release its hold.

Similar Species: The Pacific lamprey, *Entosphenus tridentatus*, is common from Alaska to southern California. It is landlocked in Goose and Clear Lakes in California. Its prey mainly consists of salmon and steelhead trout. This species is very similar to the East Coast form.

SLIME EELS OR HAGFISHES: Family Myxinidae

These are distinguished from lampreys by the four pairs of short barbels on the head, lack of eyes, a somewhat smaller size, and a continuous dorsal fin.

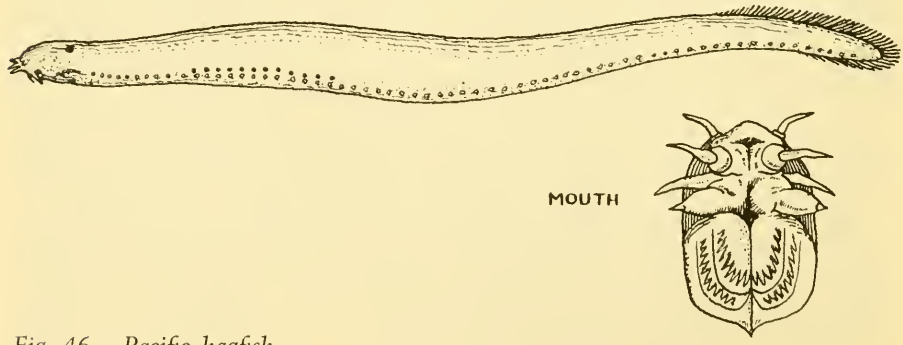


Fig. 46. Pacific hagfish.

The prey is usually dead or dying fishes though it is possible that healthy fishes may sometimes be taken. Thus, they may be considered a sort of cross between a parasite and a scavenger. They bore into the prey, usually at the neck with the tongue, or they may even enter the body through the mouth. Once inside, the prey is eaten from inside out and only a sack of skin is left. Great losses to fishermen have occurred when hagfishes have entered the bodies of fish caught in gill nets or on set lines. Over a hundred hagfishes have been retrieved from the body of a single fish. They seem to locate prey by smell rather than by sight as do lampreys. They are mainly nocturnal and lie buried in the mud most of the time.

Hagfishes are sometimes caught on lines themselves. They swallow a hook deeply, even as far as the anus.

These fishes do not enter fresh water to breed. Small numbers of large, shelled, adhesive eggs are laid in the sea where they sink and stick to the first object they touch.

The name "slime eel" is derived from the fact that they can exude huge, dripping quantities of mucus from the skin when caught. A large one can fill a two gallon bucket with slime exuded from the mucus glands on the sides.

Their distribution is world-wide in temperate seas, and they seem to prefer cool water.

PACIFIC HAGFISH: *Bdellostoma stouti*

Size: Up to 2 feet.

Distribution: From southeastern Alaska to southern California.

Identification: Same as for the family.

Habits: This hagfish is especially abundant around Monterey Bay at depths of 10 to 20 fathoms. It preys chiefly on disabled or netted rockfish, *Sebastodes*, and various flounder. About twenty large eggs are deposited on rock or shell bottom in early summer, but breeding may occur at any time of year. These eggs are oblong and connected together by hooks at their ends.

Similar Species: The slime eel (hagfish), *Myxine glutinosa*, is the Atlantic form, found from the arctic south to Cape Hatteras. It keeps to deeper waters at the southern end of its range and reaches 18 inches in length.

THE SHARKS AND RAYS: Class Chondrichthyes (*"cartilage fish"*), Subclass Elasmobranchi (*"plated gills"*)

This subclass omits the strange ratfishes which will be discussed later. It is a very ancient group which has been in existence for over 300 million years. With all that time available for their evolution, it would be expected that sharks and rays would be very diverse in body form and habits, but they are not. Evidently their body plan has been a successful one, and it has not been varied nearly as much as the bony fishes for instance. There are but two basic body plans, a cylindrical one as seen in sharks and a flattened one as seen in rays.

This group is a mysterious one. The underwater swimmer should avail himself of every opportunity to observe its species since the habits of very few are well known. For this reason, the groups will be considered here in some detail. Furthermore, because of the great amount of talk, based on little knowl-

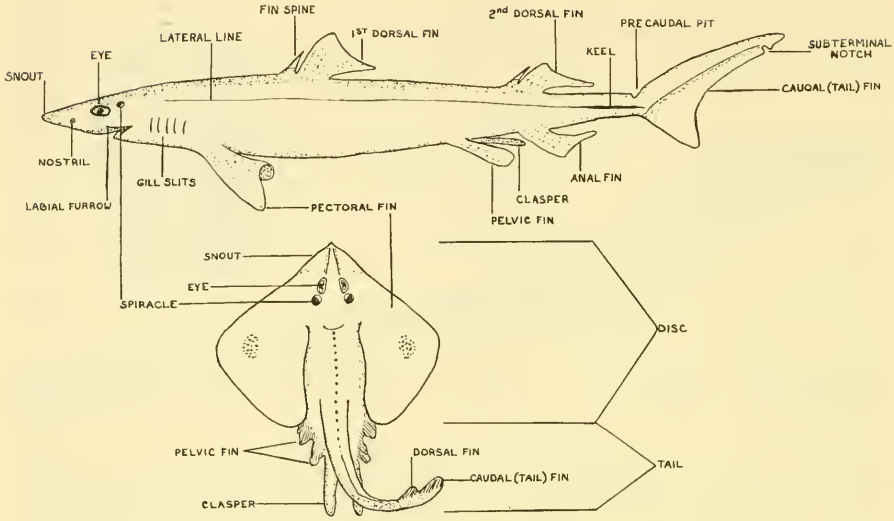


Fig. 47. The external anatomy of sharks and rays.

edge, about some species, particularly sharks, one has to be careful in his judgment about what to believe.

This is a marine group with the exception of very few species. The entire skeleton is made up of gristle or cartilage. An enormous advance has been made over agnathans in that sharks and rays possess true jaws and paired fins (the pectorals and pelvics), characteristics which give great versatility in habits and motion. The best field characteristics are (1) the possession of several gill slits, (2) the tail in which the upper lobe is much the largest (heterocercal tail), (3) the position of the mouth under a pronounced snout, and (4) the lack of true scales of the type seen in bony fishes.

Sharks and rays possess scales of a very interesting and basic type. These are called the "dermal denticles" or "placoid scales" and are anatomically very similar to the teeth of all vertebrates (with the exception of agnathans) in that they possess enamel, dentine, and pulp cavity. The scales are scattered over the body of sharks and rays and are usually small, giving, however, a certain roughness to the skin. Very large sharks have large scales which can produce cuts on a diver. Formerly, carpenters capitalized on this roughness and used sharkskin, or shagreen, as sandpaper until the advent of more modern abrasives. In some parts of the body, these scales are greatly enlarged, on the bodies of skates, *Raja*, for instance. The sting ray's spine, the sawfish's saw teeth, and, most notably, the teeth in the mouth of all sharks and rays are all evolutionarily modified and enlarged placoid scales. Even we humans owe what few teeth we have left to their origin as placoid scales.

The teeth of sharks and rays are modified greatly for a wide variety of functions and are constantly replaced from the inside of the jaws as the functional teeth on the outside of the jaws are worn down or lost (*fig.* 48). A few species have several rows of teeth functioning at once, particularly the shell-crushing kinds such as Port Jackson sharks and eagle rays.

Fig. 48. Top. One of the authors is holding a small nurse shark, Ginglymostoma. *The barbels, used for locating prey by taste and touch, are clearly shown. In spite of the docile nature of this shark, it has occasionally been known to bite. Bottom. The inside of the jaws of the tiger shark,* Galeocerdo, *are lined with several rows of teeth. Those at the bottom of the picture replace those at the top as the latter are worn down.*

Most sharks and rays possess a hole just behind the eye. This is the spiracle and is exceedingly important to the bottom-living species for the purpose of breathing. In the normal breathing pattern of fishes, water enters the mouth, passes the gills where oxygen is extracted, and is expelled through the gill slits. In bottom-living forms, notably rays, it is not possible for water to enter the mouth for the simple reason that in so doing the animal, with its underslung mouth, would gulp more sand and mud than water. Therefore, water enters the spiracle into the throat and gill cavity. Pelagic and mid-water species such as mackerel sharks do not need the spiracle and may lose it completely. In man a vestigial spiracle is seen in the Eustachian tube, which connects the ear and throat cavities.

We can understand something of the durability of the sharks and rays over the centuries by examining their senses and body form. While it is true that sharks and rays possess very limited brain power, some senses are remarkably developed. The sense of smell is powerful and is the chief means of finding food. The lateral line, also important in finding food, is sensitive to low frequency water vibration and "hears" in water in the same way, perhaps, as our ears perceive air vibrations. The ampullas of Lorenzini on the snout sense hydrostatic pressure and perhaps also temperature change. Thousands of tiny sensory crypts on the skin act like taste buds. The ear, entirely internal, gives the animal a sense of position and balance. It is no wonder that, with such equipment for smelling, "hearing," and "feeling" water, sharks and rays have little need of eyesight. The eyes are quite capable of defining images, but their extreme nearsightedness is well known. It has been experimentally shown that a dogfish will not react by sight to an object until it is only one foot away. Nevertheless, sight should by no means be underestimated until more is known about it. One "sense" that is poorly developed, it seems, is that of response to pain.

In body form, sharks and rays are also well adapted. They are admirably streamlined and beautiful to watch under water. Though none are as fast or as maneuverable as the best among the bony fishes, the advance over lampreys and hagfishes is great. One shark, *Carcharinus*, a ground shark, was clocked at 40 mph over a very short distance (Budker, 1947). The fins of typical sharks are beautifully designed hydrodynamically but fairly rigid in contrast to those of bony fishes and are thus used mainly as planing devices like the fins on a submarine. The vertical fins, dorsals and anal, prevent yawing and rolling. The paired fins, chiefly the pectorals which are moderately movable, give a dynamic or changing pitch equilibrium. In other words, they are used to point the shark's body up or down. The tail fin propels the shark and also turns it left or right. The upper lobe of the tail fin is longer, which tends to drive the head down. To counteract this, the head is flattened and tends to point the body upwards. If we add up all of these factors, we see that sharks have, in spite of fin rigidity, remarkable stability in all dimensions, even though maneuverability and some speed are sacrificed; sharks, for instance, cannot stop suddenly but can only come to a gradual halt. Stability is desired because it reduces to a minimum the amount of effort needed to keep the fish going in any one direction. It makes all motion extremely smooth and graceful. Certainly, sharks are as graceful as any animals that swim. Stability is also

desirable for another reason. Sharks are heavier than water and possess no swim bladder as do the bony fishes. They must swim slowly but constantly or they will sink. Some species have become so attuned to constant motion that they use it to help circulate water through the gills and will suffocate if held stationary. This constant motion of the active species makes them appear menacing.

The fastest sharks are those in which the body is shortened and compact and the tail lunate, that is, has nearly equal lobes. These are the mackerel sharks, family Isuridae. One shark family, the hammerheads or Sphyrnidae, has made an attempt to increase maneuverability by extreme flattening and widening of the head which is then used as a forward rudder. Another attempt in increased maneuverability resulted in the flattened rays, where the pectoral fin has been greatly expanded and has gradually taken over all locomotion.

All sharks and rays have internal fertilization, which is uncommon in bony fishes. The males possess claspers on the pelvic fins which are inserted into the females. A few sharks lay eggs and are said to be oviparous. Most are ovoviviparous, the eggs hatching in the female's body and the young being born alive shortly thereafter. A few sharks are truly viviparous as are mammals and have a "placenta" by means of which the females nourish the pups as they grow. Some ovoviviparous rays have a sort of internal feeding in which the female's "uterus" secretes a milky substance for the young. Sharks and rays produce few young, the recorded extremes in numbers varying from one to eighty-two, and perhaps averaging below twenty.

All sharks and rays are carnivorous. A great variety of food is eaten, but the sharks are mainly fish-eaters and the rays mainly mollusc- and crustacean-eaters. A few are cannibalistic. Tiger sharks are especially liable to eat other sharks and rays when these are disabled or hooked. Hammerheads like to eat rays. Gudger (1932) reports finding fifty-four spines of the eagle ray, *Aetobates narinari*, and sting ray, *Dasyatis say*, in the head and jaws of one large hammerhead. There is a record of the skate, *Raja*, eating other small rays.

The Sharks: *Order Pleurotremata* (*"side openings"*)

The typical shark is commonly visualized as a large, ferocious, swift predator with very little on its single-track mind other than the general destruction of all life of the sea, including man. We shall soon see how incorrect this vision is, for while it is true that some sharks are among the largest and most voracious of animals, most sharks do not conform to such a pattern.

In general, the sharks are fairly stout and subcylindrical of body, but several are almost as flattened as rays and even parallel the rays in habits. Others are long and slim. They range in size from 18 inches to nearly 60 feet. Several dwell in the deep sea, and some pelagic species are brightly luminescent.

Even though we must lay aside the stereotyped idea of what a shark looks like, there are three characteristics that all sharks possess: (1) five to seven gill slits on the sides just back of the head (hence the name "Pleurotremata"), (2) pectoral fins that may be large or small but are never connected to the head, and (3) definite eyelids. In all of these traits they differ distinctly from rays.

The various sharks are best told apart by shape and action. Except for a few species, they offer little in the way of pattern or coloration as an aid to identification.

Sharks are predominantly fish-eaters, but they are neither fast nor agile enough to catch fast healthy fish so a great part of their diet consists of the disabled or slower fishes. They prefer the easy mark, a wounded fish or a straggler. (Exceptions to this are the fast and active members of the family Isuridae, the mackerel sharks.) Sharks, contrary to popular account, do not have to turn on their sides or backs to bite, even though they occasionally do so.

We shall examine the various sharks' diets under later species discussion, but one item of diet deserves more than fleeting attention. This concerns the ever-discussed question: Do sharks attack man? The answer is an undeniable yes. But we must be careful in this assertion to be attentive to the circumstances under which attack is most likely to occur and which species might be responsible.

There is a great tendency to overdramatize the possibility of attack. This was particularly damaging to the morale of service men deployed in "shark waters" during the last war. There is an equal tendency toward debunking. Having met sharks and not having been chewed to bits, some people, especially underwater swimmers, have made the extreme assertion that sharks are not dangerous at all. The authors have heard some underwater swimmers claim that sharks are cowards. This seems to be based on the fact that these unfortunate people had once or even several times met a shark which happened to run when aggressively approached.

Sharks seem to hunt their prey in a manner somewhat as follows. The first stimulus to feed comes from two sources: smell (olfaction) and, to a lesser extent, reception of low frequency water vibration (through the lateral line). These have the effect of increasing the speed of the shark's movements, causing it to make short hunting turns and figure eights which are of an exploratory, food-seeking nature. These responses reinforce the original olfactory stimulus and also notify other sharks of the presence of food through the stimulus of low frequency vibration. Gradually, as the shark or sharks approach the food, the exploratory turns become more and more direct until the food is struck. Sight may play a part in these last stages. Contact with food is the final stimulus which brings on the "feeding mood." At this stage, sharks are extremely aroused, active, dangerous, and not discriminating in taste. Tiger sharks, *Galeocerdo*, have been known to become so excited when in the "feeding mood" as to bite blindly at any object including sacks of coal, old shoes, and tin cans.

The sharks that are implicated in attack on man are:

1. White Shark or Man-Eater, *Carcharodon carcharias*. This is the sole deliberate attacker and is always dangerous. It does not seek out man but is liable to attack because it habitually eats large-sized prey. It is aggressive, and its triangular, trenchant teeth (to 2 inches long in a 15-foot specimen) are extremely efficient. Large ones can swallow objects as large as a whole man. Fortunately, this shark is not common.

2. Tiger Shark, *Galeocerdo cuvier*. This common species is more nocturnal than most sharks. It reaches large size, has large, trenchant teeth, and is especially dangerous when in the "feeding mood." Tiger sharks commonly congregate about areas where refuse is dumped at sea.
3. Hammerhead Sharks, *Sphyrna* species. This maneuverable species grows to large size and is possibly guided to food more quickly than other sharks because of the widely separated nostrils. The teeth are rather small.
4. Mako Sharks, *Isurus* species. These are the fastest sharks that swim and are among the most aggressive. They may be dangerous under certain circumstances even though they are almost exclusively fish-eaters.
5. Lemon Shark, *Hypoprion brevirostris*. It seems that this is a disagreeable and unpredictable species that may, when large, be dangerous.
6. The Ground Sharks, Black-Tipped Sharks, etc., *Carcharinus* species. Any large members of this genus may be dangerous. The teeth are large and trenchant.
7. Sand Shark, *Carcharias taurus*. There are some doubtful records of persons being bitten by this shark.
8. Blue Shark, *Prionace glauca*. This is a pelagic species, long reputed to be dangerous. There are few records of attack.
9. Leopard Shark, *Triakis semifasciata*. This is a small shark which has attacked divers on the Pacific coast.

The conditions under which shark attack is likely are not very well known. Springer (1943), in the best work yet published on this subject, has thoroughly studied and compiled a list of well-authorized cases of attack. The following analysis is largely adapted from him and from Budker (1947):

1. Influence of Time of Day. There is an increase of frequency of attack with increasing darkness. The bulk of attacks occur at dusk, but records of attack are known for almost every time of day and night. Increased frequency of attack at dusk is probably due to decreased visibility with darkness and increased shark activity then.
2. Influence of Water Clarity. As is the case with dusk, decreased visibility means that sharks increase dependency on their lateral line for feeding.
3. Influence of Water Depth. The danger seems to be slightly greater at or near the surface. Sharks are in shallower water at night rather than during the day. Nevertheless, there seems to be little or no danger in shallow waters inshore of surf or inside of coral barriers. Sharks must at least have access to deeper waters through channels or inlets. Sharks as a whole are most abundant in fairly shallow waters not far offshore.
4. Influence of Temperature and Geographical Location. Springer has mapped the cases of shark attack on a world-wide basis, and it is apparent that sharks are most dangerous in tropical and subtropical waters in temperatures of over 66° Fahrenheit. The incidence of attack is far higher in southeastern Australia than anywhere else in the world. The beaches of Sydney are fenced in, so great is the danger of attack thought to be. Otherwise, shark attack does not seem to be concentrated at any one place.

5. Influence of Movement. Sharks seem to be attracted by inert objects at the water's surface. During the last war, it was urged that men in the water stay in a group and keep moving slowly. The effect of movement on sharks is poorly understood.
6. Influence of Various Scents.
   a. Refuse. Continuous dumping in any one area will soon train sharks to visit there frequently. Many food scents are attractive to sharks and dumping grounds are often danger spots to be avoided.
   b. Blood. This is the strongest attractant of sharks. Almost any shark may be dangerous in the presence of blood, which serves to drive them into a frenzy leading up to the dangerous "feeding mood." De Witt (1955) records an instance of a 3-foot leopard shark, *Triakis*, attacking a diver when blood was in the water. Fast (1955) states that there is "a strong possibility that with the present increase of spearfishing along our [Pacific] coast, the number of attacks by sharks will increase. Those individuals who indulge in this sport should . . . avoid seepage of blood, fish juices, or other attractants."
   c. Man. Sharks seem neither attracted nor repelled by the scent of man.
   d. Shark Repellents. During the last World War it was found that decomposing shark flesh had a repellent effect on sharks. Further investigation by the United States government during World War II led to the development of cupric acetate cakes, which can have up to 100 per cent effectiveness (but usually less) in repelling sharks from baited lines for 3 to 4 hours. Springer lists several of these experiments in which baited lines, some repellent-treated and some not, were used to fish for sharks. The repellent lines were vastly less attractive to the sharks, and most bites on repellent lines were made before the repellent had had a chance to dissolve in the surrounding water.

      There are no proven color-cloud repellents as is sometimes supposed, but sound may occasionally serve to repel sharks. The definitive work on the effect of sound on fishes is yet to be done.

To these factors we add several suggestions for an advisable course of action when the swimmer is in the presence of sharks under water.

1. Observe all you can about the shark's behavior. Try to identify the shark. Identification is most important. The swimmer's actions should be very different if he meets a white shark than if he meets a nurse shark.
2. Don't panic. Keep moving in a fishlike way, smoothly and regularly. Try to stick fairly close to protected places, like coral heads or rock outcrops.
3. If there are several of you, stay close together.
4. Avoid blood and offal in the water.
5. If attacked, fight back. This may serve to drive the shark away. The most efficient way to disable a shark is to grasp a pectoral fin tightly as the shark passes by and then to slit open its belly or gills with a knife. This, however, is not a job for amateurs.
6. Don't attack sharks. They may look docile and timid and present an easy target, but a shark, if attacked, cornered, or wounded is very liable to

turn on the swimmer. To draw a shark's blood in the water would be most foolish. This would only serve to incite this shark and draw others to the scene.

Under water, sharks possess a puzzling mixture of ferocity and timidity. Their large size, abundance in shallow and comfortably warm waters, and the many unknown facets of their behavior make them ideal subjects for observation and study. With the elimination of doubt, overconfidence, and hysteria, the underwater swimmer is in the unique position of being able to study these creatures firsthand.

The Primitive Sharks

There is but one family of these protoselachians ("shark forerunners") remaining in the seas today. It is the sole survivor of the ancient stock that gave rise to modern sharks and is distinguished from them in its primitive jaw suspension, dentition, and other anatomical characters.

PORT JACKSON SHARKS: Family Heterodontidae

The Latin name of the family refers to the fact that the teeth are of two kinds; those in the front of the mouth are small and pointed for grasping and those in the back are flattened like molars for crushing. There are two large dorsal fins, both preceded by a stout spine. The family contains only one genus of wide distribution, but not occurring in the Atlantic.

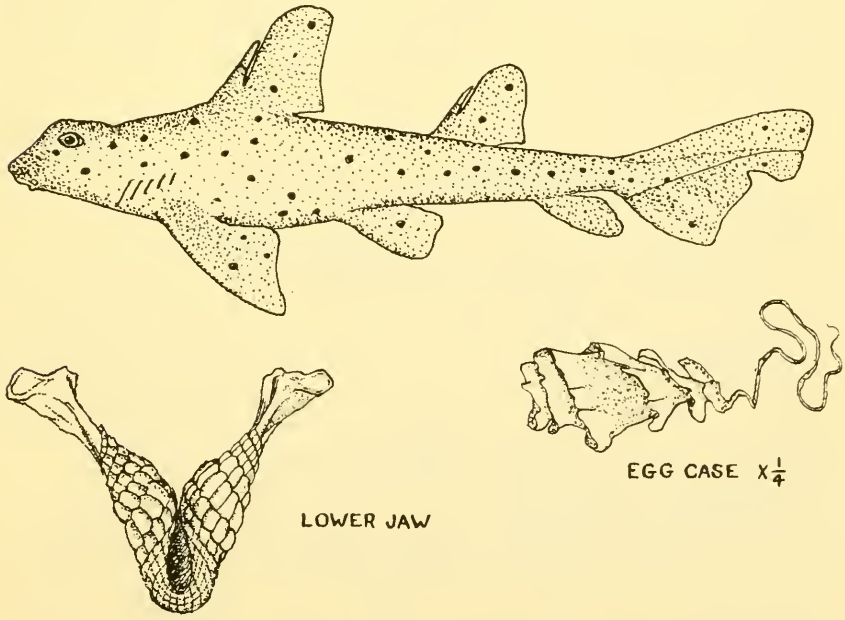


Fig. 49. Port Jackson shark.

PORT JACKSON SHARK (HORNED SHARK): *Heterodontus francisci*

Size: Up to 4 feet.
Distribution: Point Conception to the Gulf of California.
Identification: Same as for the family.
Habits: This is a fairly common shark living near kelp in shallow or deep water. It keeps to the bottom and eats hard-shelled invertebrates which it crushes with its strong molar teeth. The large and unmistakable eggs may sometimes be found wedged in among rocks near the low tide zone.

The Modern Sharks

These sharks are divided into three large groups. The rays are derived from them.

Notidanoids: *Superfamily Notidanoidea*

These most primitive of modern sharks comprise a rare and poorly known group. They reach large size and are mostly in moderately deep water of 100 to 400 fathoms, only occasionally coming within the depth range of the diver. The single dorsal fin, long, cylindrical body, and the presence of six to seven gill slits are good field marks. They are widespread in the temperate and tropical waters of the world.

COMB-TOOTHED OR COW SHARKS: Family Hexanchidae

The teeth of these sharks are unique, being completely unlike in the two jaws. These large sharks are found in all warm oceans but are not common, it appears. They are ovoviviparous. Identification is made easy by the presence of but one dorsal fin.

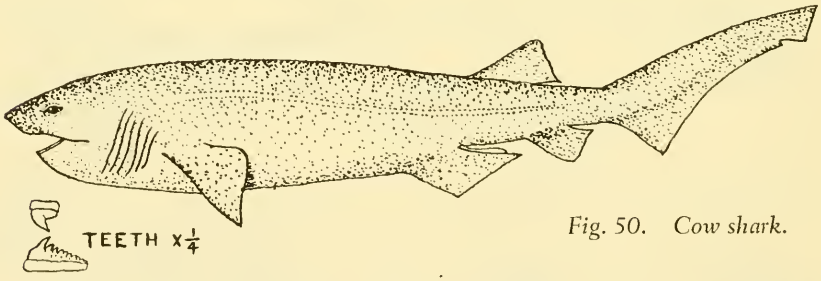


Fig. 50. Cow shark.

COW SHARK (SIX-GILLED SHARK, GRISET, MUD SHARK): *Hexanchus griseus*

Size: Up to 15 feet, exceptionally to 26 feet. Matures at 6 feet.
Weight: Up to 1,300 pounds.
Distribution: All warm seas. In the Atlantic from Cape Hatteras to the Caribbean. In the Pacific from southern California to British Columbia. Not rare in Cuban waters and off San Diego.
Identification: Dark brown or gray with a light streak along the lateral line. There are six gill slits.

Habits: This is primarily a deep-water form living at over 50 fathoms. It gets closer to the surface in northern waters and at night. Probably it is a voracious predator on large fishes such as dolphin, swordfish, marlin, and other sharks. Except when feeding, it is probably a sluggish fish. Those who have eaten the flesh report it to have a strong purgative effect.

Similar Species: The perlo or seven-gilled shark (*Heptranchus perlo*) is another widespread, large, voracious fish which looks like the cow shark, but is without the light, lateral line stripe and has seven gill slits.

Galeoids: *Superfamily Galeoidea*

This is the group of the great majority of modern sharks. All have five gill slits and two dorsal fins which are not preceded by a spine. Because these are active sharks, there is a tendency to reduce or even lose the spiracle. In separating the families, the size and placement of the dorsal fins and gill slits are of importance.

CARPET SHARKS OR NURSE SHARKS: Family Ginglymostomidae

The two large dorsal fins are both posterior to the pelvics. Gill slits three, four, and five are over the pectoral fins and four and five are so close together as to appear as one. The mouth is preceded by two short barbels and is connected to the nostrils by a short groove. As befits bottom-living, sluggish sharks, the lower tail lobe is poorly developed. These sharks are ovoviviparous.

NURSE SHARK (GATA): *Ginglymostoma cirratum*—*Figure 48*

Size: Averages 5 feet. Commonly up to 8 to 10 feet. Exceptionally to 14 feet.

Distribution: Rhode Island to Brazil, but not commonly north of Cape Hatteras. Also on the western coast of Mexico.

Identification: The young have small black spots, which disappear with maturation, scattered over the dingy brown body. The head is large and flat, and the eyes small.

Habits: This is a sluggish, inoffensive, and rather fearless shark which is very common in shallow tropical waters. It is often seen lying in a protected hole or cove or under a ledge near coral heads. Pairs come into very shallow water in order to mate. At such times they loll about with their dorsal fins out of water. It is quite a sport among local boys to grasp them by the pectoral fins in order to secure a ride. When mating, the male holds the female by a pectoral fin with his teeth. Thus, female nurse sharks are likely to look a bit ragged about the pectorals after a few mating seasons. This shark, although normally inoffensive, will definitely bite when annoyed.

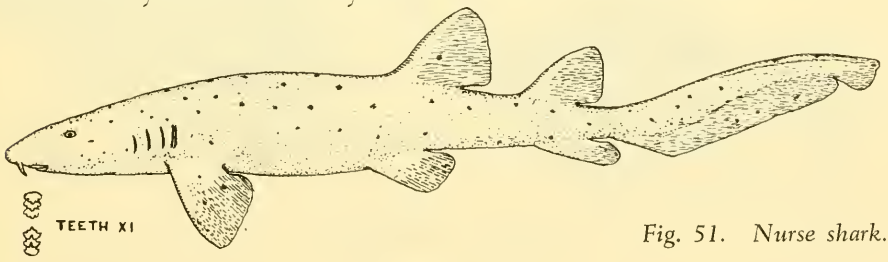


Fig. 51. Nurse shark.

Nurse sharks nose about coral and seaweed in search of food which consists of a great variety of small fishes and invertebrates. At times, they eat refuse, amounting almost to scavengers. Several rows of small teeth in each jaw form a crushing or holding dentition.

CAT SHARKS: Family Scyliorhinidae

The two dorsal fins are nearly equal in size and posteriorly placed, the first being behind or over the pelvics. The tail fin is much like that of the nurse sharks with a poorly developed lower lobe. The fourth and fifth gill slits are over the pectoral, and the spiracles are fairly large. This group is rather uniform with many small, cat-eyed, prettily patterned species, most of which live in deep tropical and temperate waters beyond the range of the diver. Cat sharks are most common in the South Pacific and Indian Oceans, but are world-wide in distribution. The common spotted dogfishes, *Scyliorhinus* species, of Europe belong in this family. They are oviparous as far as is known.

SWELL SHARK: *Cephaloscyllium uter*

Size: Up to 3 feet.

Distribution: Monterey Bay to Acapulco, Mexico.

Identification: Ground color is brownish yellow. Barred with black and spotted with black and white.

Habits: This is the only cat shark which is common inshore. It may be seen in kelp beds particularly. It presumably eats a wide variety of animal foods, especially fish, and can swallow surprisingly large objects with its capacious mouth. The common name is derived from its habit of inflating like a puffer when molested. The flesh will cause diarrhea if eaten.

SAND SHARKS: Family Carchariidae

The two dorsal fins and the anal fin are of nearly equal size and the posterior margin of the first dorsal is just over the anterior margin of the pelvic.

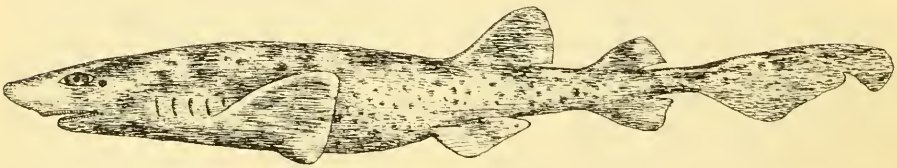


Fig. 52. Swell shark.

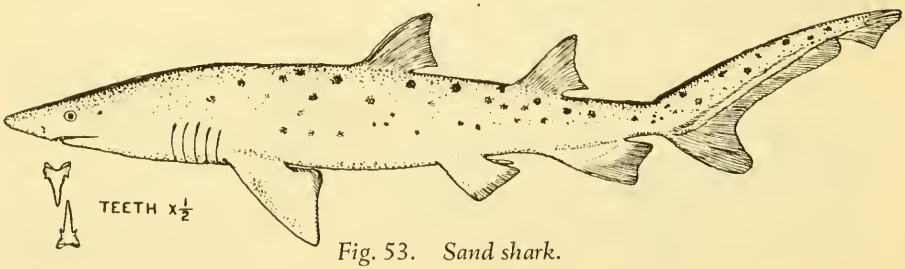
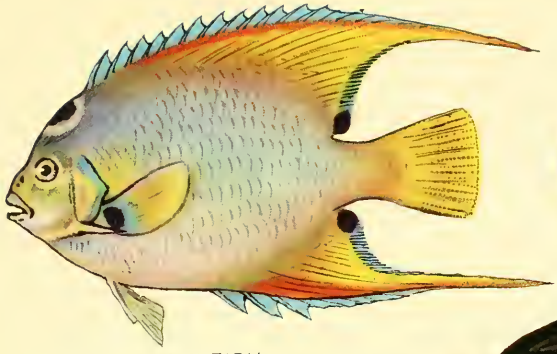
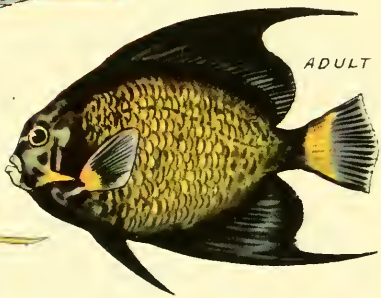


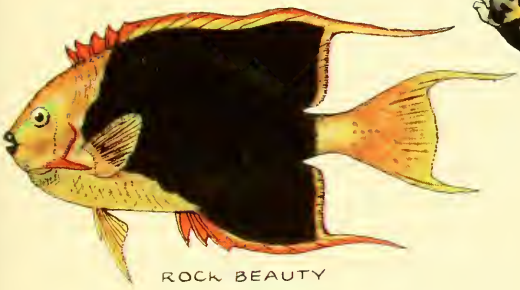
Fig. 53. Sand shark.



QUEEN ANGELFISH

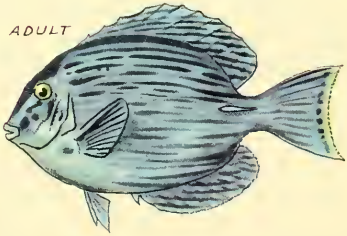
FRENCH ANGELFISH

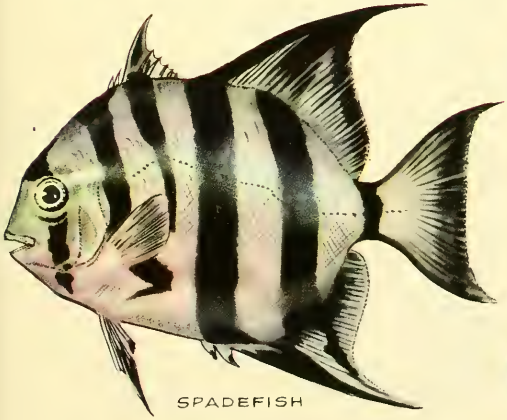




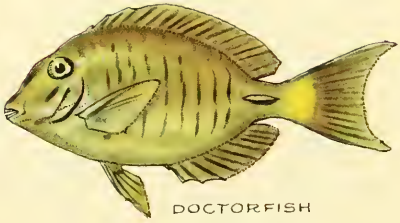
ROCK BEAUTY

BLUE TANG



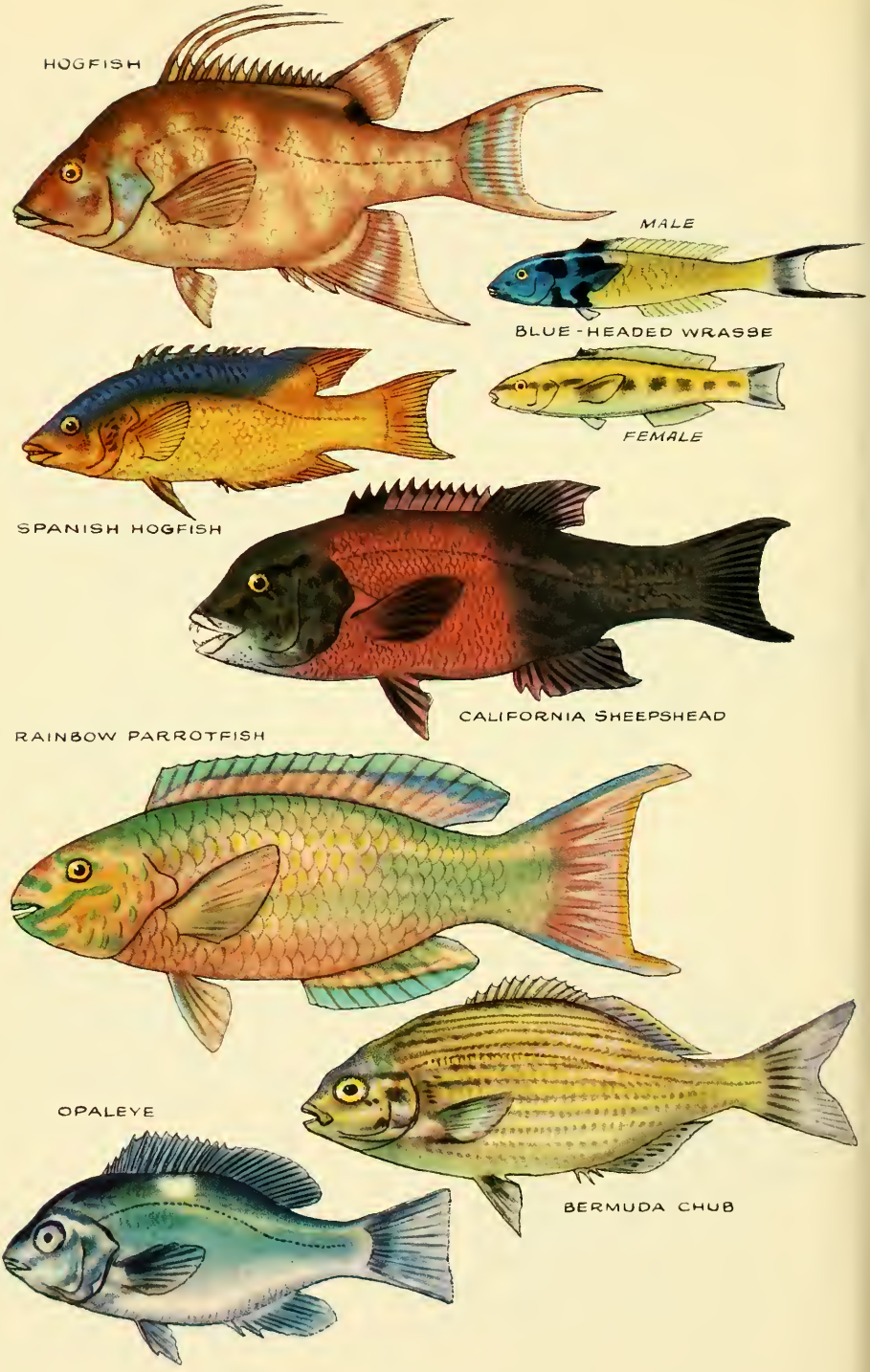


SPADEFISH



DOCTORFISH

COLOR PLATE 7



COLOR PLATE 8

All of the gill slits are anterior to the pectoral fin. There is only one genus in the family. The species are ovoviviparous and are cosmopolitan in warm waters.

SAND SHARK (SAND TIGER): *Carcharias taurus*

Size: Averages 4 to 6 feet. Up to 9 feet.

Weight: Up to 250 pounds.

Distribution: Maine to Brazil. Most common in warm temperate waters and rare in the tropics.

Identification: Grayish brown above, fading to white below. The young have light spots and blotches which disappear with age.

Habits: This is the most common large shark swimming over sandy beaches. It is fairly sluggish but can move at good speed when the occasion demands. It feeds principally at night on fishes and squids and occasional large crustaceans, the sharp, pointed teeth serving admirably to hold such slippery prey. They may feed in large schools in very shallow water. Although there are no records of attacks on man, this shark is to be respected.

MACKEREL SHARKS: Family Isuridae

These are unquestionably the most active, swiftest, and most voracious of sharks. The modifications toward swiftness are good field marks. These are (1) a compact and torpedo-shaped body, (2) a high first dorsal fin placed at the highest point on the back, (3) reduced second dorsal and anal fins of nearly equal size, (4) a narrow caudal peduncle reinforced with lateral keels, and (5) a lunate tail in which the lobes are of nearly equal size. In many of these respects, they resemble the mackerels and spearfishes which are among the very swiftest of bony fishes. The gill slits are anterior to the pectoral fin. There is no spiracle.

The coloration is characteristic and like that of most pelagic fishes being a sea-blue above and white beneath, an example of obliterative coloration (Chapter 2).

These are primarily fish-eaters and are found in all temperate and tropical seas. They are ovoviviparous.

MAKO (SHARP-NOSED MACKEREL SHARK): *Isurus oxyrhincus*

Size: Averages 6 feet. Up to 12 feet and possibly a little larger.

Weight: Averages 150 pounds. Up to 1,200 pounds or more.

Distribution: Tropical and warm temperate Atlantic. Common in the Bahamas. In summer to New England.

Identification: Anal slightly posterior to second dorsal. Coloration is slate-blue above, abruptly changing to dirty white below. The snout is conical and sharply pointed. The teeth are slender and recurved for holding fish.

Habits: This may be the swiftest shark that swims. It is pelagic and pursues swift, schooling fish such as mackerel and herring for food. Occasional squids and sea turtles are taken. This fish is best known for its habit of leaping spectacularly from the water especially when hooked, but it is most often seen basking at the ocean's surface, solitary or in small schools, with the large dorsal fin protruding. It can be dangerous, particularly around boats. It's near relative, the bonito shark of the Pacific, *Isurus glaucus*, has been known to attack men and

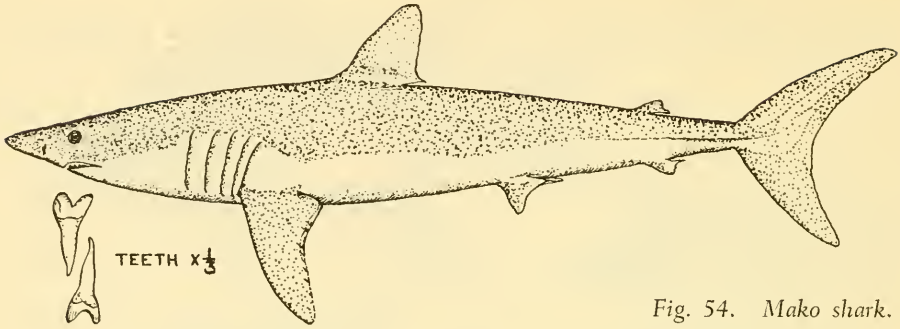


Fig. 54. Mako shark.

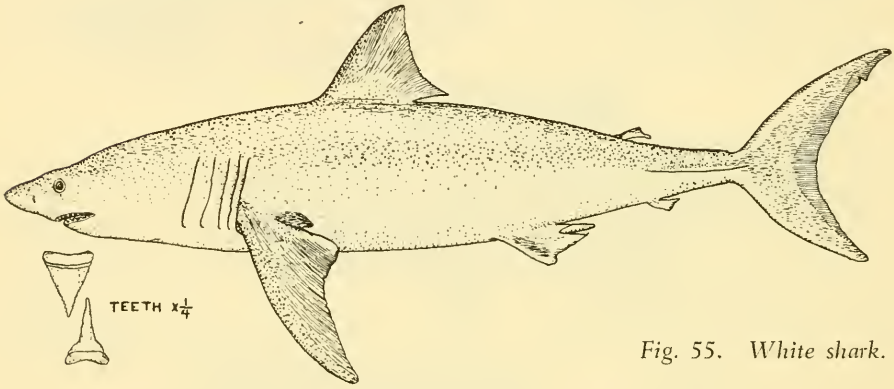


Fig. 55. White shark.

boats. The young are few (one to five) and large at birth (20 pounds). This is an excellent food fish.

Similar Species: The Pacific bonito shark or Pacific mako, *Isurus glaucus,* may be identical to the Atlantic form. It is found from Monterey Bay to the south and over the entire South Pacific.

The porbeagles and mackerel sharks (*Lamna* species) replace the makos in the Atlantic and Pacific in water below 60° Fahrenheit. These are stouter sharks than the makos and have the second dorsal and anal directly opposite each other. The generic name *Lamna,* is derived from a Greek word depicting a horrible, man-eating fish, and was used to intimidate naughty children.

WHITE SHARK (MAN-EATER): *Carcharodon carcharias*

Size: Averages 8 to 12 feet. Rare over 15 feet. Recorded up to 36½ feet.

Weight: At 21 feet, one weighed 7,100 pounds and its liver weighed 1,005 pounds.

Distribution: Nowhere common. Most common near southeastern Australia. Occurs in all warm temperate and tropical seas.

Identification: Similar to mako and mackerel sharks, but the second dorsal and anal fins are even more reduced; the teeth are triangular with serrate edges and the shape stouter. Coloration is slate-gray with a black axillar spot. Over 15 feet, the color fades to lead-white.

Habits: This may be the most voracious thing that swims with the exception of the killer whale, *Orca*. It is active, fast, and very powerful and is responsible for most of the authenticated reports of attacks on man. Though principally pelagic, it will enter very shallow water. It has been known to attack boats without provocation or especially when hooked or harpooned. The white shark feeds on large fishes, sea turtles, and even sea lions. One shark was found with a 100-pound sea lion nearly intact in its stomach. Another specimen of 15 feet was found to contain a large Newfoundland dog. Another 15½-footer contained two 6-foot sharks.

The young are few in number and large, being over 100 pounds in weight when born.

Similar Species: One recently extinct *Carcharadon* is worth mention because of its spectacular size. Only the teeth have been found, but they indicate a body length of over 60 feet. A full-grown man could have stood upright in this huge fish's mouth.

BASKING SHARKS: Family Cetorhinidae

These are the largest fishes found in temperate waters. They are much like mackerel sharks in form, but the gill slits are very long, the mouth huge, the snout short, and the teeth minute and very numerous. The skin is very rough and abrasive. They are ovoviviparous. There is but one species of circumpolar distribution.

BASKING SHARK (BONE SHARK): *Cetorhinus maximus*

Size: Commonly to 30 feet. Exceptionally to over 40 feet.

Weight: Commonly to 8,600 pounds.

Distribution: Temperate seas of both hemispheres. South to Cape Hatteras and California. Not arctic but gets into very cold water. There is a center of abundance to the southwest of Iceland.

Identification: The color is a light gray to brown, lighter on underside.

Habits: The common name, basking shark, is derived from the habit of basking at the water's surface with the enormous dorsal fin and even part of the back out of water. At such times, it is very easy to approach this shark in a boat or in the water. Nevertheless, it should be remembered that this huge fish is

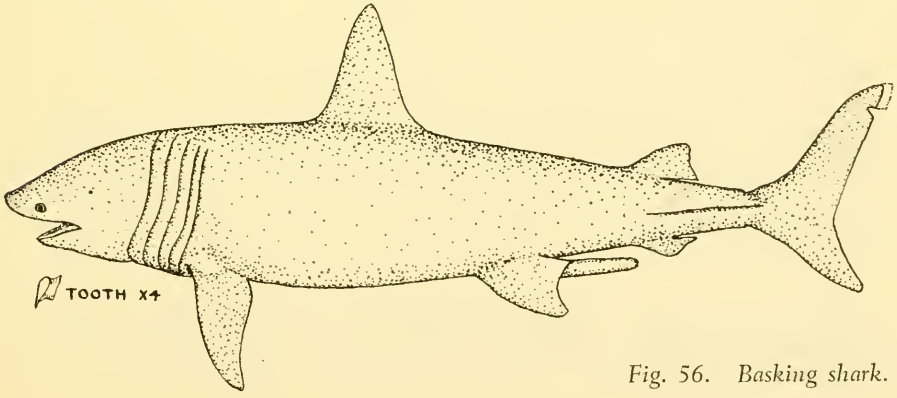


Fig. 56. Basking shark.

extremely powerful. One stroke of the tail can easily stave in a small boat. These fish travel singly, in small groups, or in large schools of up to a hundred. At times, several may travel in tandem and have been mistaken for sea serpents. As is often the case with many giant fishes, these are plankton feeders, having fine gill rakers with which to strain their food from the water. When feeding, they travel open-mouthed through the water. Excellent pictures of this may be seen in the motion picture *Men of Arran*. Basking sharks sometimes leap from the water. They have been decimated by oil hunters; a single liver yields from sixty to six hundred gallons of oil. They are usually seen only in summer when the plankton supply is good, retreating to deeper water and possibly not feeding in winter.

WHALE SHARKS: Family Rhineodontidae

There is no fish that approaches the whale shark in size except the basking shark. The last two gill slits are over the pectoral fin, and the first dorsal is fairly far back over the small pelvics. The tail fin is huge. The mouth is large and not preceded by a snout. There is only one species of cosmopolitan tropical distribution.

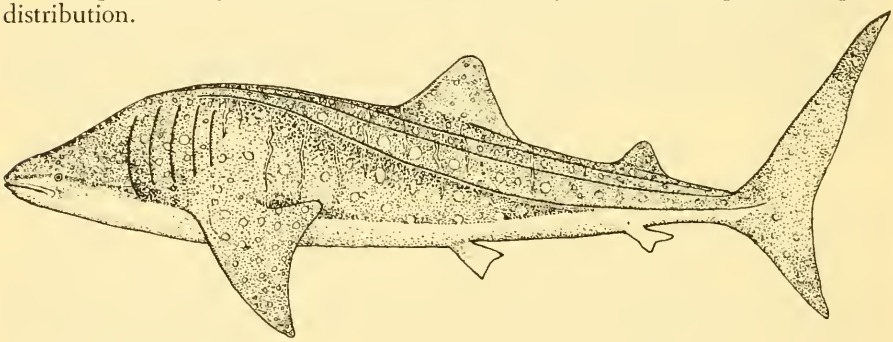


Fig. 57. Whale shark.

WHALE SHARK: *Rhineodon typus*

Size: To 60 feet or more. Very rare over 30 feet.

Weight: A 38-foot whale shark weighed 26,594 pounds.

Distribution: All tropical seas. Most numerous off the Philippines and the coasts of southern California and western Mexico.

Identification: The coloration is a unique gray to red or green crossed with yellowish stripes and spots. Three prominent ridges run down the sides.

Habits: This is a very inoffensive fish, so sluggish that it has been rammed by boats on several occasions. Despite this, it can probably travel swiftly. The feeding habits, teeth, and gill rakers are much like those of the basking shark. It also basks on the surface and may school, though it is usually solitary. It sometimes gulps plankton, small fish, or squids while standing vertically beneath the school of food.

THRESHER SHARKS: Family Alopidae

These are large sharks with a large, extended upper tail lobe. Otherwise they resemble mackerel sharks.

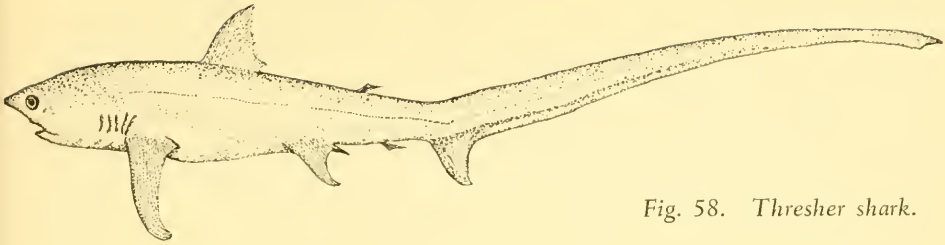


Fig. 58. Thresher shark.

THRESHER SHARK (FOX SHARK): *Alopias vulpes*

Size: Matures at 14 feet. Rarely to 20 feet.

Weight: Matures at 500 pounds. Rarely to 1,000 pounds.

Distribution: Cosmopolitan in all warm seas. North to the state of Washington and to New England in summer.

Identification: Blackish to slate and brown, sometimes with a metallic luster. The teeth are rather small.

Habits: This is a pelagic species of ferocious appearance, but it is quite harmless and is almost exclusively a fish-eater. It provides one of the very few examples of cooperative feeding among fishes, another being found among the puffers. Several sharks herd moderate-sized, schooling fishes such as mackerel, herring, or bonito into tight groups with the aid of their tails. Attack is thus made easier. They may also use the tail to stun prey. The thresher is swift and voracious. One was found off Scotland containing a bushel of fish in its stomach. Contrary to rumor, threshers do not attack whales. It is a good food fish.

SMOOTH DOGFISHES: Family Triakidae

The first dorsal is large and just behind the pectoral fin. The second dorsal is reduced in size, but it is not as reduced as in the similar requiem sharks, Carcharinidae, so is noticeably larger than the anal fin. The lower lobe of the tail fin is poorly developed. The last two gill slits are over the pectoral, and the body is slender and tapering. These fish are very much like the requiem sharks and are characteristic of shallow, warm temperate, and some tropical waters the world over. However, they tend to small size and are considered harmless. There are both ovoviviparous and truly viviparous species. The flesh of most species is good as food.

SMOOTH DOGFISH: *Mustelus canis*

Size: Averages 2½ to 3½ feet. Up to 5 feet.

Distribution: Winters from Cape Hatteras to Chesapeake Bay. Arrives in New England from May to June when the bottom water warms to about 45° Fahrenheit. Rare in tropics, but known to Brazil.

Identification: Plain gray to brown. Can change shade from dark gray to pale, pearly white when over a light bottom. The change takes two days for maximum effect. This is one of the few sharks able to change color.

Habits: This, like all smooth dogfishes, is a shallow water fish rarely straying beyond the 10-fathom limit except in the southern part of its range. It is most common in bays and may enter brackish and fresh water. The teeth are arranged

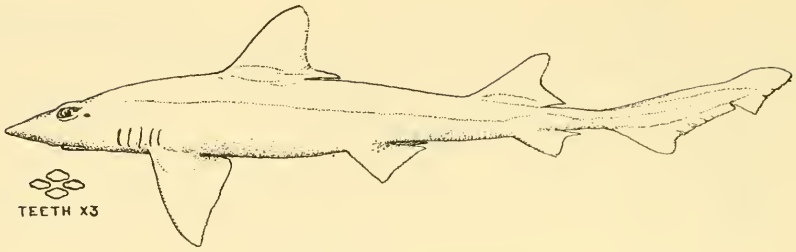


Fig. 59. Smooth dogfish.

in a pavement and are adapted for shell crushing. Thus, it is a crab-eater primarily, though a few lobsters are taken. It also takes small fishes, squids, and some molluscs and worms. It may scavenge. This is the fish on which experiments on shark feeding methods have been done. Smell is the chief aid for finding food, the shark moving its head from side to side and therefore sensing food alternately more strongly with one nostril than the other until the direction of the food is detected. It has been shown that plugging one nostril causes the fish to take much longer to find food. This shark is viviparous. As many as twenty-seven foot-long young are born in June and July. The gestation period is ten months.

Similar Species: The gray smooth hound, *Mustelus californicus,* is found from northern California to Baja California and the sicklefin smooth hound, *Mustalus lunulatus,* from San Diego to Colombia. Both are very much like the East Coast species in habits and appearance.

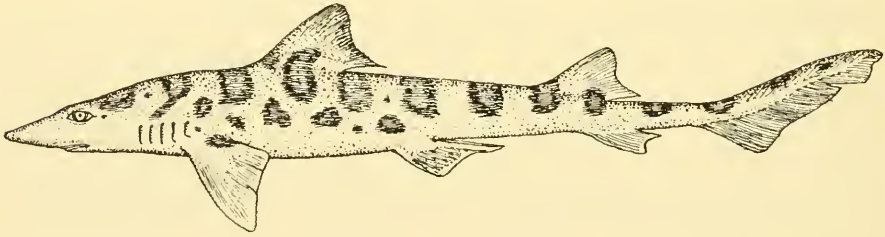


Fig. 60. Leopard shark.

LEOPARD SHARK: *Triakis semifasciata*

Size: Females mature at 3½ feet and grow to 5 feet. Males grow to 3 feet.

Distribution: Oregon to Baja California.

Identification: The pattern of black crossbars and spots is unmistakable.

Habits: This is a bay and shallow-water shark similar to the smooth dogfish. Although small, this shark is easily incited by the presence of blood and will bite.

Similar Species: The brown smooth hound *Triakis henlei,* looks very much like the *Mustelus* species. It is very common in San Francisco Bay and other enclosed California bays.

REQUIEM SHARKS: Family Carcharinidae

These sharks form the bulk of "typical" modern sharks and are characterized by a large first dorsal fin which is usually far anterior to the pelvic. The second dorsal is much reduced, just above and of a similar size to the anal. Added field marks are the position of the fourth and fifth gill slits over the pectoral fins and the characteristically shaped caudal fins, which is preceded by well-developed precaudal pits. These fishes all have a well-developed third eyelid or nictitating membrane which serves to keep the eyes free of foreign matter (*fig. 64*). Spiracles are small or missing. The teeth are bladelike, triangular, and trenchant, and only one row is functional at a time. Requiem sharks are ovoviviparous or viviparous and characteristic of warm temperate to tropical seas the world over.

TIGER SHARK: *Galeocerdo cuvier*

Size: Common at 12 feet. Said to reach 30 feet, but largest recorded in Atlantic was 18 feet.

Weight: Common at 850 pounds.

Distribution: Common in the Caribbean. North to Cape Hatteras and rarely to Cape Cod. On the West Coast to southern California. Cosmopolitan in warm temperate and tropical seas.

Identification: The snout is very blunt and rounded and the labial furrow prominent. The sides are blotched and striped, but this pattern disappears with age. The teeth are large, few in number, and characteristic (*fig. 48*).

Habits: This is one of the most voracious sharks, having extremely catholic tastes in food. It eats sea turtles, sea lions, fishes large and small, crustaceans, offal, and other sharks. It also preys on sting rays, the spines having little effect on the shark. One, when captured, vomited the arm of a man who had been murdered at sea and dismembered. This is the most abundant large shark of the Caribbean and seems to be attracted by the cast-off offal of slaughterhouses. In such dumping areas, it may be dangerous. There are records of its having attacked man, though these are few even in areas of shark abundance. In spite of the foregoing, this is a sluggish shark, normally becoming active only when aroused to the "feeding mood." One expects to see tiger sharks in shallow water near land, but they may be encountered almost anywhere, even in harbors or the deep sea. It is the most prolific shark, normally bearing thirty to fifty living young. The largest number of young ever recorded in a brood, eighty-two, was from a female of this species. The young are small, only 18 inches long at birth.

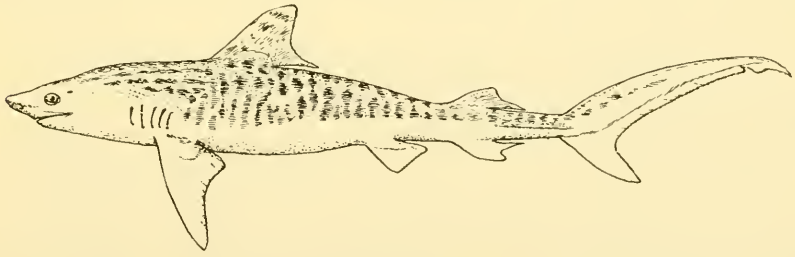


Fig. 61. Tiger shark.

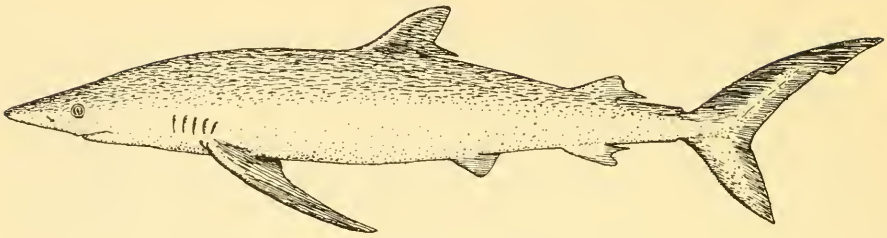


Fig. 62. Blue shark.

BLUE SHARK: *Prionace glauca*

Size: Commonly 9 to 12 feet. Rarely to 20 feet.

Weight: 164 pounds at 9 feet.

Distribution: Cosmopolitan in warm temperate and tropical seas. North to British Columbia in the Pacific and Nova Scotia in the Atlantic. Not found in shallow-water areas such as the Gulf of Mexico.

Identification: The coloration is a beautiful indigo blue, fading to pure white below. The body is slim, the pectorals very long, and the snout very long and pointed. The first dorsal is rather far back for a requiem shark.

Habits: This is the most common pelagic shark, held in fear by sailors and in contempt by whalers. It is normally sluggish except when aroused. There are few recorded attacks by this species on man, but it should not be counted as harmless. It is most commonly seen at the surface, basking with the dorsal fin out of water or following after ships in search of food. For the latter reason, they have been named *chiens de mer* by the French. When hunting prey, they are active and have been observed to repeatedly blink with the third eyelid. They are most active at night. The blue shark's greed is practically legendary. It feeds on all sorts of small pelagic fishes and squids. Frequently, it gathers in great numbers about whaling ships to share in the carcass. At such times, when the sea is clouded by blood, the sharks flounder all about the whale. Occasionally, the whalers strike the sharks with their blubber spades and horribly mutilate them, but even when so wounded, they go right on feeding until some of their fellows dispose of them. There is a record of one captured blue shark, which had had its liver removed, trying to catch a mackerel after being thrown back in the water. Another gutted blue shark was recaught on a hook baited with its own intestines. This shark is viviparous and rather prolific, producing as many as fifty-four pups at almost any time of year.

LEMON SHARK (YELLOW SHARK): *Negaprion brevirostris*

Size: Matures at 7 feet. To 11 feet rarely.

Weight: 265 pounds at 9½ feet.

Distribution: Cape Hatteras to Brazil. Most abundant in the Caribbean. Also in the South Pacific and Indian Oceans.

Identification: The first dorsal is small for a requiem shark and the second dorsal rather large. The color is yellowish brown, fading to a distinct yellow on the underside. The snout is broad and rounded.

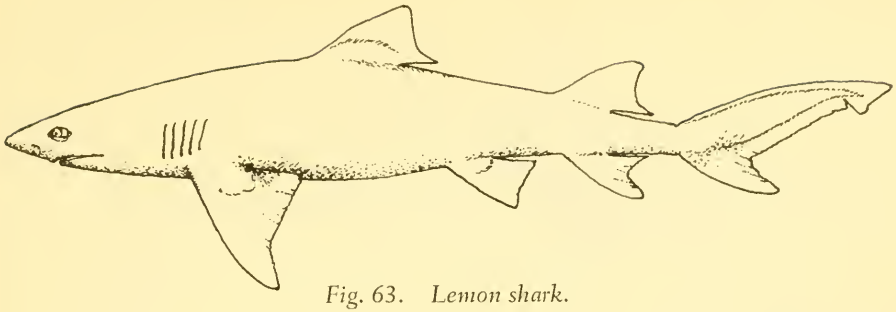


Fig. 63. Lemon shark.

Habits: This is a strictly inshore shark and may be seen around harbors and sounds. It even enters such fresh waters as the Amazon. It is mainly a fish-eater. It is one of the most common of Caribbean sharks and is not to be trusted, its disposition supposedly being erratic. This shark is viviparous, bearing young in the spring and summer.

GROUND SHARKS: *Carcharinus* species

This is the largest genus of sharks, containing many species that are difficult to identify even by experts. Therefore, they will be considered as a group. Their distribution is world-wide in warm temperate and tropical waters.

Identification: As a group, the ground sharks are bluish or grayish to brownish, generally lighter on the belly. The first dorsal is very high and placed forward. The second dorsal is over the anal and, like the anal, is small. The upper precaudal pit is very large. There is no spiracle.

Habits: These are inshore and reef-inhabiting sharks of fish-eating habits largely, but they will take many foods. The larger ones are not to be trusted. The teeth are trenchant and large. When the cry "shark" goes up along inshore waters, the cause is usually a ground shark. They are curious fish and have approached the authors to within a foot, returning several times for repeated "looks," but seldom gave trouble. In fact, they usually fled when approached, but that is no guarantee that they invariably do so. One, the Lake Nicaragua shark, *Carcharinus nicaraguensis*, is the only habitually fresh-water shark and has been known to attack people. A list of the most common species with hints for identification follows:

East Coast:

1. Cub Shark (Bull Shark, Fish Shark, Southern Ground Shark): *C. Leucas*

   This species is never found far from land. It frequently travels in groups. The diet is extremely varied, this shark can be dangerous at times. The snout is very short, broad, and rounded for the genus. It attains a length of 10 to 12 feet, though rare over 8 feet. From Cape Hatteras to Brazil and strays to Massachusetts.

2. Small Black-Tipped Shark (Spinner Shark): *C. limbatus*

   The eyes are large, and the pectoral, dorsal, anal and lower caudal fins are tipped with black. It is rather small, averaging 6 feet and reaching 9 feet. This is an active, swift, largely pelagic species. It may school at the

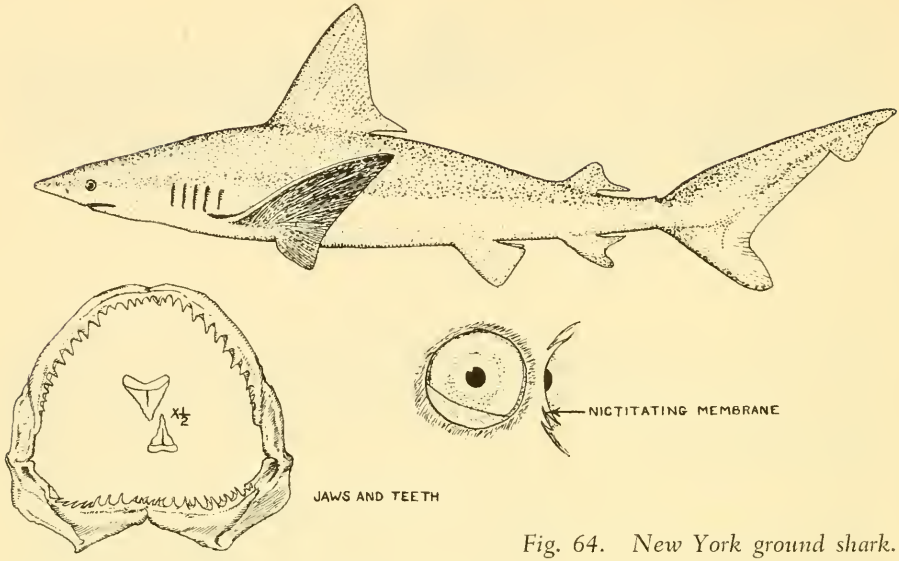


Fig. 64. New York ground shark.

surface and frequently leaps from the water, turning as it does so. A tropical species which strays to Massachusetts.

3. White-Tipped Shark: *C. longimanus*
   This shark has a very broad and rounded first dorsal tipped with grayish white. The snout is rather short. It may reach 13 feet and is the most pelagic of the ground sharks. Found in the tropical and warm temperate Atlantic.
4. New York Ground Shark (Brown Shark, Sand-Bar Shark): *C. milberti*
   The first dorsal is very high and placed far forward, and the second dorsal is directly over the anal. It reaches 8 feet and 200 pounds. This is the most abundant ground shark in the shallow waters along the mid-Atlantic Coast. It may enter river mouths and is the only large shark commonly found in Long Island Sound. It also enters the canals of Venice. It is largely a bottom feeder on all sorts of fishes and invertebrates. The young are born in shoal waters in the north from June to August. From southern New England to Brazil. Also in the Mediterranean and off west Africa.

West Coast:

5. Bay Shark: *C. lamiella*
   This is a large shark of up to 15 feet, most common in bays and shallow waters. The fins are not dark-tipped. From southern California to Mazatlán, Mexico.
6. Gambuso: *C. azureus*
   This shark reaches 10 feet, is more pelagic than the former, and has dark-tipped fins.

SHARP-NOSED SHARK: *Scoliodon terrae-novae*

Size: Averages from 2 to 2½ feet up to 3 feet.
Weight: Averages 8 to 10 pounds.

Distribution: Common in the Caribbean and Gulf of Mexico and in summer to Cape Hatteras. Straggles to New York.

Identification: This shark is a southern counterpart, ecologically speaking, of the smooth dogfish. The small size of the second dorsal fin, lack of spiracles, short gill slits, and prominent labial furrow serve to identify it. The color is brown to gray with the dorsal and tail fin edged in black. The body is quite slim.

Habits: A typical beach, surf, and estuary species, this shark has never been found more than one or two miles from land. It eats a wide variety of small invertebrates and fishes and has not endeared itself to fishermen because of its habit of preying on their baits. It is viviparous.

Similar Species: The Pacific Sharp Nose, *Scoliodon longurio,* is found from southern California to Panama. It reaches 3½ feet and 9 pounds. It is rare in scientific collections but should be common in bays in its range and should be looked for.

SOUP-FIN (OIL SHARK, TOPE): *Galeorhinus zyopterus*

Size: Females reach 6½ feet, males up to 6 feet.

Weight: Females reach 100 pounds, males 60 pounds.

Distribution: Pacific Coast from San Francisco to Cedros Island.

Identification: Similar to the blue shark but has short pectoral fins, no precaudal pit, and is brown to gray in color. The dorsal, caudal, and pectoral fins are tipped with black.

Habits: This voracious shark eats all sorts of fishes, squids and other invertebrates, and even carrion. It is the most valuable shark commercially and is sought for its liver which is rich in vitamin A. The flesh is very good, and the fins are used to make the famous shark's-fin soup. This is an inshore species,

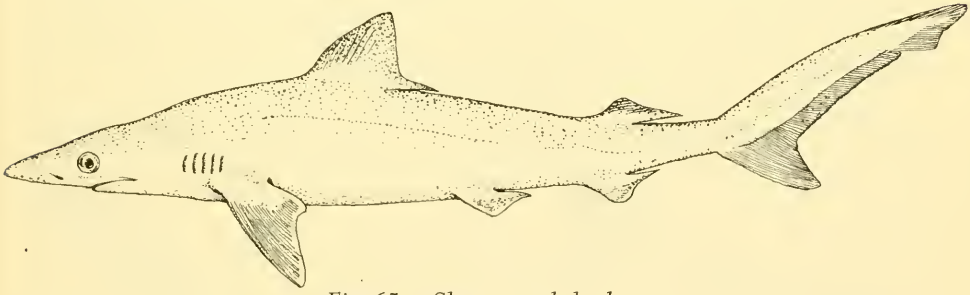


Fig. 65. Sharp-nosed shark.

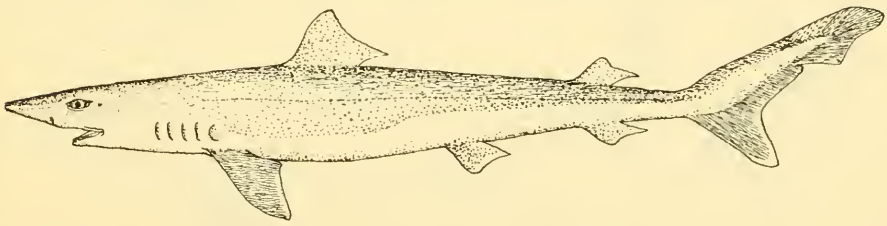


Fig. 66. Soup-fin shark.

common both at the surface and on the bottom. The litters are large, averaging thirty-five and recorded from six to fifty-two. Gestation may take one year. It is ovoviviparous.

HAMMERHEADS: Family Sphyrnidae

The widely expanded and flattened head serves to separate these sharks from the otherwise similar requiem sharks. The eyes and nostrils are at or near the ends of the head's extensions. Supposedly, the head, acting like a forward rudder, gives these sharks greater maneuverability than other sharks. The very large and wide-set nostrils are highly efficient. These sharks are usually among the first to arrive when blood is in the water. Hammerheads are found in all warm temperate and tropical seas.

HAMMERHEAD: *Sphyrna zygaena*

Size: Matures at 7 to 8 feet. Averages 8 to 11 feet. Reaches 15 feet.

Weight: 900 pounds at 12 feet.

Distribution: All tropical and subtropical seas. North to Cape Hatteras (rarely to Cape Cod) and southern California.

Identification: Slate to brownish gray in color.

Habits: This is a strong-swimming, voracious, active, surface shark, found at sea or inshore or even in tidal, brackish waters. Like many other sharks, it often basks at the surface with its caudal and dorsal fins protruding. Hammerheads have a definite liking for sting ray meat. They will also eat fishes of various kinds and other sharks as well. Great numbers of sting ray and catfish spines have been found in the heads, jaws, and bodies of hammerheads, apparently causing no discomfort to the shark. This shark is known to be dangerous to men even though the teeth are rather small. The northerly migration of schools of hammerheads in the summer consists mainly of small, 6-foot sharks. They are viviparous, bearing up to thirty-seven young.

Similar Species: Sphyrna zygaena is merely one of three very similar hammerheads. The great hammerhead, *Sphyrna tudes,* is the largest of these. It reaches

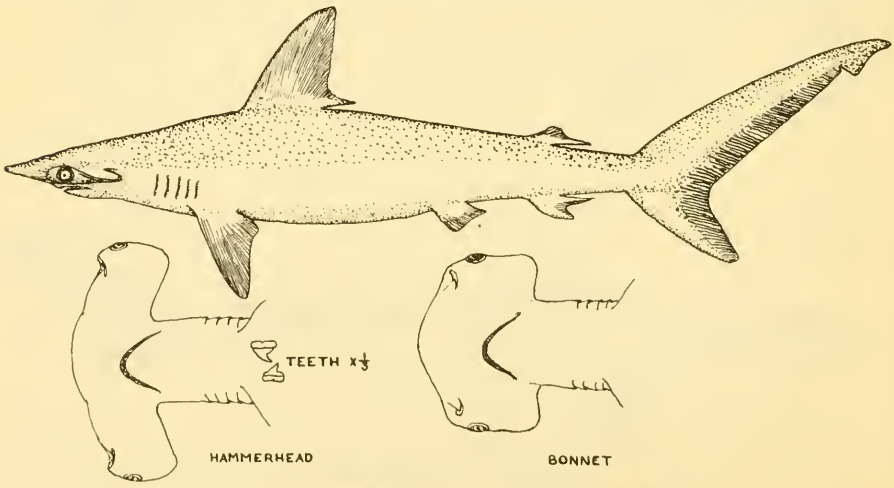


Fig. 67. Hammerhead shark and bonnet shark.

17 feet and 1,500 pounds. The little 5-foot bonnet shark, *Sphyrna tiburo,* is found north to New Jersey and San Diego. It is a shallow-water, bay species, and is harmless. The kidney-shaped head separates it from the three typical hammerheads.

Squaloid Sharks: *Superfamily Squaloidea*

This is the third and last subdivision of the modern sharks. The best field characteristic is the complete lack of the anal fin. They also possess two dorsal fins both of which are sometimes preceded by a stout spine and fine gill slits which are short and entirely in front of the pectoral fins. Spiracles are present and reproduction is ovoviviparous. Presumably, this group gave rise to the rays.

SPINY DOGFISHES: Family Squalidae

The dorsal fin spines are large and the labial furrows are long. These are small slim sharks of world-wide distribution. Many of them live in deep water, and all have very large eyes. The tail fin has no subterminal notch.

SPINY DOGFISH (PIKED DOGFISH, GRAYFISH): *Squalus acanthius*

Size: Averages 2½ to 3 feet. Up to 4 to 5 feet. The females are the largest.

Weight: Averages 7 to 10 pounds. Up to 20 pounds.

Distribution: Subarctic North Atlantic south to Cape Hatteras. North Pacific south to Point Conception.

Identification: Slate to brown color with yellowish spots on sides. The shape is very slim and subcylindrical.

Habits: This is neither a swift nor very active shark. Nevertheless it is voracious, feeding avidly on small fishes such as herring, menhaden, and small mackerel. It also eats invertebrates, such as jellyfish, and refuse. It is a cold-water form, characteristic of waters of 43° to 59° Fahrenheit. Both its northern and southern movements are determined by these temperatures, and it is thus like the common mackerel except that its temperature range is a little lower. During the hot months and in the south it is found in deep waters down to 100 fathoms. It is by far the most numerous shark in cooler waters, usually found traveling in huge schools inshore, in brackish water, or a few miles offshore. These schools are constantly on the move, so their appearance is somewhat erratic. From one to fourteen young are born in the late autumn offshore after two years of gestation. When caught, this shark thrashes violently curling its body like a bow and striking out with the slightly poisonous dorsal fin spines. The wounds these produce may be painful. The flesh is good and is usually sold as "grayfish."

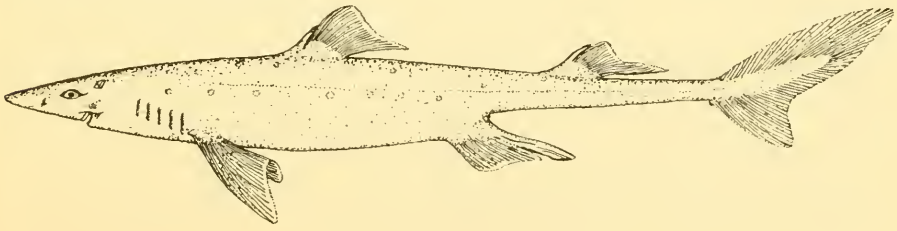


Fig. 68. Spiny dogfish.

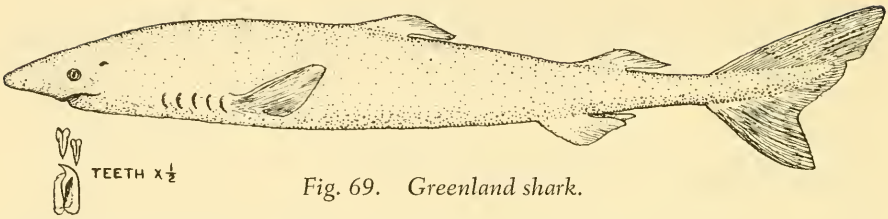


Fig. 69. Greenland shark.

SLEEPER SHARKS: Family Dalatiidae

The dorsal and pectoral fins are reduced in size, and the gill slits are short. These sharks are as sluggish in appearance as they are in reality. The teeth are very different in the two jaws. Many are inhabitants of the deep sea and have luminous spots. Their distribution is world-wide, and they are ovoviviparous.

GREENLAND SHARK (SLEEPER SHARK, GURRY SHARK): *Somniosus microcephalus*

Size: Averages 8 to 14 feet. Possibly to 24 feet. The females are larger than the males.

Distribution: Arctic seas to Cape Cod.

Identification: The color is coffee-brown to dark gray with tinges of violet. There may be faint, darker crossbands.

Habits: This is the largest arctic fish and the only arctic shark. It may live in water as cold as 28° Fahrenheit, or as warm as 55° Fahrenheit. It probably lies near or on the bottom, rising only to feed and may be counted as the most sluggish of large sharks, offering no resistance to capture. In spite of this, it seems to be able to catch seals as well as large fishes such as halibut and salmon, though it will also eat crustaceans and jellyfish. It seems to be irresistibly attracted by carrion. Therefore, whalers know it well. In spite of rumor to the contrary, it attacks neither living whales nor men in kayaks, and it is quite harmless. The flesh is intoxicating and poisonous if eaten fresh, but is wholesome if dried or allowed to become partly rotten.

Similar Species: The Pacific sleeper shark, *Somniosus pacificus,* is found south to southern California. Its habits are like those of its Atlantic cousin.

ANGELFISHES: Family Squatinidae

These raylike fishes are shown to be sharks by the possession of gill slits on the side of the "neck," pectorals which are not attached to the head, and free eyelids. They also possess characteristics which are superficially raylike: much flattened body form, enlarged pectoral and pelvic fins, two small dorsals placed far back, a row of spines along the mid-back, and eyes and enlarged spiracles on the top of the head. They are not to be considered the evolutionary link between sharks and rays, but they are midway between those two groups in habits. Thus, they are bottom-living but still use the tail in a sculling, sharklike manner for locomotion, little use being made of the pectorals except for steering. They are ovoviviparous and world-wide in distribution.

MONKFISH (ANGEL SHARK): *Squatina dumeril*

Size: Matures at 3 to 3½ feet. To 5 feet.

Weight: At 4 feet weighs 60 pounds.

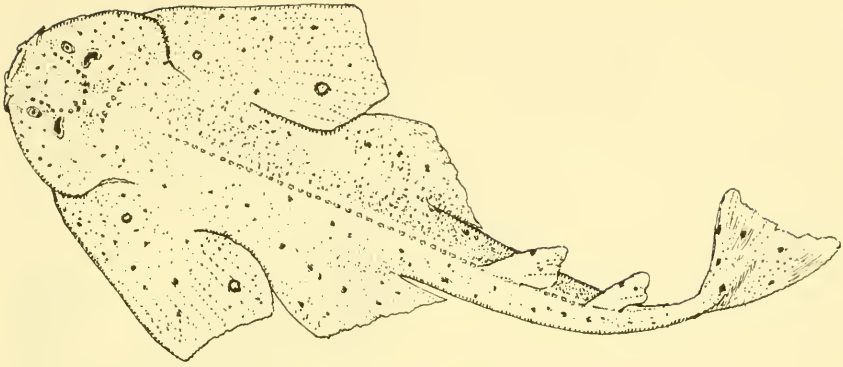


Fig. 70. Monkfish.

Distribution: Summer visitor to mid-Atlantic states. Most common near Chesapeake, south to the Gulf of Mexico and the Caribbean. Not really plentiful anywhere.

Identification: Blue to ash-gray above with spots and mottled pattern. May have some reddish tints.

Habits: In summer, this is mainly an inshore fish. It lies on the bottom and may partly cover itself with sand or mud as rays are wont to do. From this vantage, it ambushes flatfish, skates, mullet, and other fishes. It also eats crustaceans and molluscs, which it crushes with its strong jaws. In winter it strays to water as deep as 700 fathoms. The young are born in early summer inshore in numbers up to twenty-five at a time. This shark has powerful jaws and may inflict a painful bite if molested. The teeth are small and numerous. The term "angel shark" refers to the angel-wing shape of the pectorals.

Similar Species: The California angel shark, *Squatina californica,* is of similar size to the Atlantic forms. It is found from Alaska to southern California and is rather common in the south. The European monkfish, *Squatina squatina,* gets much larger, 8 feet and 170 pounds, and is very plentiful in Europe.

Rays: *Order Hypotremata* (*"openings beneath"*)

Among the most remarkable of the animals of the sea are the rays, sometimes grouped as the order Batoidei. Most of them are greatly flattened, but just as there are raylike sharks, there are also sharklike rays, so body form is not distinctive. The significant characteristics are (1) the enlargement and continuation of the pectoral fins onto the head, (2) the position of the five pairs of gill slits on the underside (forced there by the overgrowth of the pectorals), and (3) the absence of lower and usually also of upper eyelids.

The rays probably developed from squaloid sharks in response to the development of expanded pectoral fins for greater mobility. The evolution of the advanced rays (Myliobatoidea) from the primitive types (Pristoidea) was the result of the following steps: (1) the pectorals took over all locomotion, (2) dorsal and caudal fins were lost, (3) the body became flat, (4) the enlarged spiracles and eyes were moved to the top of the head, and (5) the tail became

Fig. 71. One of the authors is photographing a large southern sting ray, Dasyatis *americana, four feet in diameter, which was found covered with sand sleeping on the bottom.*

distinct from the body. We see this evolutionary transition in following the changes in body form from the sawfishes to the guitarfishes to skates and torpedoes and finally to the eagle rays. This evolutionary trend is an adaptation to bottom-living. But like almost every group of animals, there are departures from the principal theme, and so the rays have also risen from the bottom to take on the more pelagic life that we see in the eagle rays and mantas.

Paralleling these evolutionary tendencies are distictive methods of locomotion. In the most sharklike and least flattened rays, the sawfishes and guitarfishes, locomotion is accomplished by powerful sculling motions of the tail as in sharks. The pectoral is used little. In the torpedoes also, propulsion is chiefly caudal, but this is probably because the disc is so inflexible, it being the location of the electric organs. The skates move almost entirely with the pectoral fins, undulating waves traveling in this fin from front to rear. Sting rays also use

undulating waves of the pectoral for slow locomotion, but flap their "wings" like a bird more than do the skates when they desire to move fast. The eagle and manta rays flap their wings exclusively and are able to move rapidly in this way. Turning in all rays is accomplished mainly or exclusively by the pectoral fins. Some rays, particularly the "flying" ones are among the most graceful of fishes. They are also among the most powerful things that swim as anyone who has hooked one can attest.

As befits their largely bottom-living habits, rays are dark on the upper surface while the lower surface remains white and patternless. The upper surface is sometimes patterned to resemble the substrate over which the animal lives.

Most rays are rather sluggish and nocturnal and, though powerful swimmers, are not as speedy as sharks or bony fishes. It is expected, therefore, that they would abandon the fish-eating diet of sharks for more easily caught food such as invertebrates. Most of them cannot see their food as they grasp it with their mouths, but must settle over the active food species with their bodies or dig for the less active ones in the bottom. They are the only fishes that are known to settle over and trap food with their bodies, but they do not envelop prey with their wings as has been supposed. Most rays possess many rows of small, sharp, or flattened teeth arranged so as to act in a grasping or crushing manner.

Rays vary in size from a few inches to 23 feet (across the pectorals) and are found all over the world from arctic to tropical waters. Some sting rays and sawfishes even enter fresh water. Rays allow close approach since they are not timid animals. By day they are often seen asleep on the bottom. They are, therefore, easy prey for the swimmer, but the authors do not consider it either very good sportsmanship nor very good sense to molest them. It must be remembered that even rather small rays are powerful, and many, if not most of them, can be dangerous, as we shall see in the following pages.

There are five major groups (superfamilies) of rays.

Sawfishes: *Superfamily Pristoidea*

These are the most sharklike of the rays. The presence of the extended snout bearing saw teeth is an unmistakable and unique identifying character. This saw can be a very formidable weapon. Sawfishes are ovoviviparous. The saw of newly born sawfish is covered by a sheath in order to protect the female.

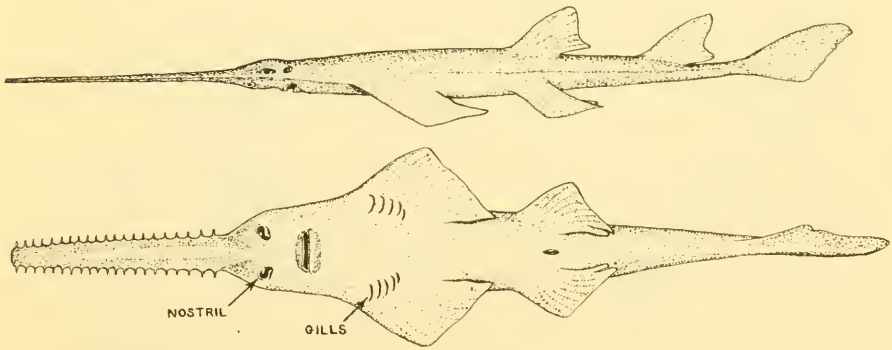


Fig. 72. Sawfish.

This sheath is lost soon after birth. The distribution of sawfishes is world-wide in warm, shallow seas. They enter brackish and fresh water. There is but one family containing a single genus.

SAWFISHES: Family Pristidae

SAWFISH: *Pristis pectinatus*

Size: Commonly to 16 feet. Reaches 20 feet or more.

Weight: Commonly to 700 pounds.

Distribution: Most common off Florida and in the Gulf of Mexico. To Cape Hatteras in summer. Also south to Brazil.

Identification: Grayish brown in color.

Habits: These bottom-living rays are most plentiful in shallow bays and estuaries, entering brackish and even fresh waters. The shape indicates a sluggish but powerful animal. They rarely rise far from the bottom except to attack schools of small fishes, such as mullet, on which they feed. The saw is used in a sideways slashing manner to stun and impale these fishes, which are later eaten at leisure. The saw also serves for poking about in the sand or mud bottom for various items of food, mostly invertebrates. It is also a powerful weapon of defense. A sawfish will not attack man unprovoked, but even small ones should not be molested. Contrary to rumor, sawfishes do not attack whales, but they may attack fairly large fishes, although rarely. The young are born in summer and autumn after about a year's gestation. They are 2 feet long at birth. Young sawfishes make excellent eating.

Guitar Fishes: *Superfamily Rhinobatoidea*

In this group, the transition from sharklike to raylike forms is complete. The disc is either distinctly heart-shaped or round. The tail is always stout, and the dorsal and tail fins are well developed. A uniform shagreen covers the body. The mid-dorsal spines are somewhat enlarged. They are ovoviviparous and found in all warm temperate and tropical seas.

GUITARFISHES: Family Rhinobatidae

SPOTTED GUITARFISH: *Rhinobatos lentiginosus*

Size: Averages 2 feet. Reaches 3 feet. The females are larger than the males.

Distribution: Most common off Florida. To Yucatan and Cape Hatteras.

Identification: Covered with small light dots over a brown to ash-gray ground color. The disc is wedge- or heart-shaped and the snout long.

Habits: Guitarfishes swim close to the bottom using sculling motions of the tail for propulsion and the pectorals for steering. They may lie half buried in mud or sand and eat small molluscs and crustaceans. They are not often encountered in water deeper than 5 to 10 fathoms and are even encountered in surf feeding on the gammarid shrimps and sand crabs, *Hippa,* found there.

Similar Species: Three West Coast species show a perfect graded transition to skates in the shape of the disc, though the tail remains stout in all.

The shovel-nosed guitarfish, *Rhinobatos productus,* is much like the East

Coast form. It reaches 4 feet or over and ranges from central California to the Gulf of California.

The mottled guitarfish, *Zapteryx exasperata,* has a shortened snout, wider disc, dark crossbands, and reaches 3 feet in length. It is found from San Diego to Panama.

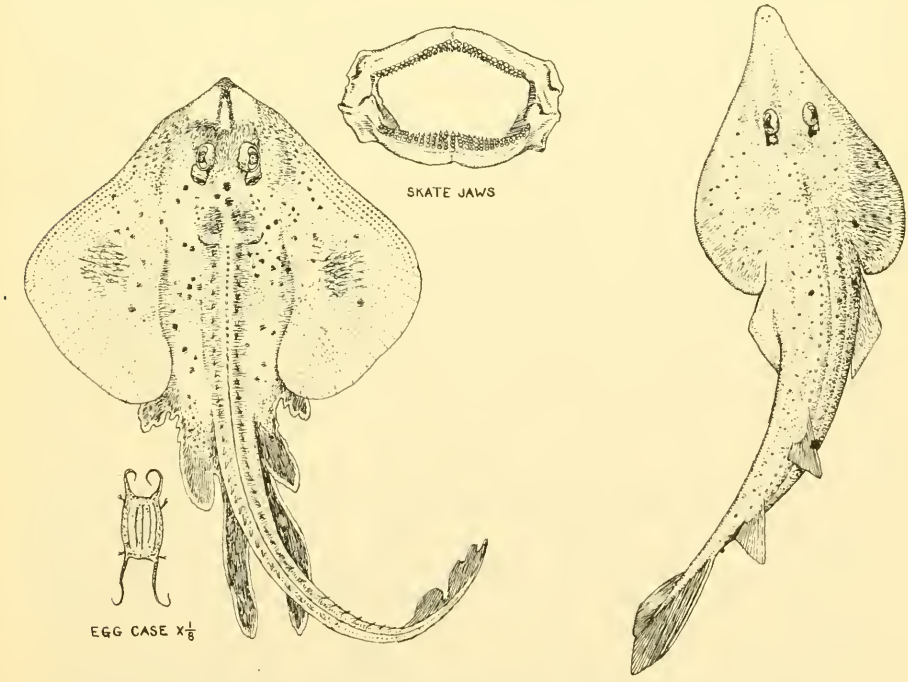
The thornback, *Platyrhinoidis triseriata,* has a skatelike rounded disc and skatelike spines on the back and shoulders. It reaches 3 feet and is found from central California to Baja California.

Skates: *Superfamily Rajoidea*

In these rays and all remaining rays, the tail is sharply marked off from the body, and the pectorals are the chief means of locomotion. Skates also have the dorsal and tail fins greatly reduced in size and the pelvic fins deeply notched so that they look double. The males possess very large claspers. The discs and tail are covered with enlarged prickles in patches which vary according to species. Skates are characteristic of temperate and arctic waters of the world. They are in the tropics, but only in very deep water. Some run up rivers. They are the only oviparous rays. The egg cases, called "sea purses" or "sailor's purses," are very common objects on beaches.

SKATES: Family Rajidae

This is the only family of skates and contains the largest of all elasmobranch genera, *Raja,* with almost a hundred species. The species of this genus have



Figs. 73 and 74. Common skate (left) and spotted guitarfish (right).

similar habits and some are difficult to identify. Therefore, skates will be considered as one group.

SKATES: *Raja* species

Skates are ground fishes found over sand, mud, gravel, or shell bottoms. They are rather inactive by day, at which time they lie on the bottom, sometimes half buried. To bury themselves, they stir up the bottom with their pectorals and let the sand or mud fall back on them. They depend a good deal on protective coloration to avoid being detected, their grayish or brownish, often spotted or mottled bodies blending in well with the substrate. When alarmed they tend to press their bodies closely to the bottom and may form a suction between their bodies and the bottom which makes them difficult to dislodge. If further alarmed, they may curl themselves into sort of a ball and lash violently with their spiny tails. Some have electric organs on their tails able to deliver half a volt. The adaptive value of such a small shock is not known. The skates are not exclusively bottom fishes. Frequently, they come to the surface to bask in the sun after the manner of many sharks. Skates, like most rays, have many rows of small, pointed or flat teeth in the jaw which form a crushing or grasping dentition. Their prey is quite varied but usually consists of crustaceans, molluscs, worms, and small to medium-sized fishes. With active prey, such as fish, their method of securing food is by ambush. They lie on the bottom until a victim comes their way, then quickly pounce on it, holding it down with their bodies, and then grasping it in their jaws. This method of capture is made necessary by the position of the jaws on the underside. Locomotion is achieved by undulating waves passing from front to rear in the pectoral fin. Skates can swim surprisingly fast, at which time the pectorals are used in a flapping motion like the wings of a bird. The tail may aid in steering.

Skates mate with their ventral sides together and are frequently caught in this position. One or both claspers are inserted. The egg capsules or sea purses (*fig.* 73) are 3 to 8 inches long and contain one to several eggs. They are laid in the summer and adhere to rocks, shells, algae, etc., hatching in four and one-half to fifteen months. The courtship and mating procedure should be easy to observe by the swimmer. Males are smaller than females by about one-third. Sometimes, several follow a single female and strike each other with the spiny parts of the pectorals. These spiny pectoral patches are also used to grasp the female while mating. Skates make excellent food. *Raie au beurre noire* is a French culinary delicacy. Skates reach 6 feet and 60 pounds but are mostly much smaller. A list of some common species follows:

East Coast:

1. Common Skate (Little Skate, Hedgehog Skate): *Raja erinacea*
   This is a small skate, reaching only 20 inches in length. The spines are in a distinctive pattern with no spines of large size directly on the midline. This is the most common New England skate, found in shoal water and to 80 fathoms, usually over a sandy bottom. It ranges from Cape Hatteras to Nova Scotia.
2. Clear-Nosed Skate (Briar Skate, Summer Skate): *Raja eglanteria*
   There are two translucent areas on the side of the snout and there is a

prominent row of spines on the midline of the back and tail. The whole tail is covered with thorns of like size. The back is spotted or barred with dark brown. Reaches 2 feet in length. Found in shallow waters from Maine to Florida but common only from Massachusetts to Delaware.

3. Barndoor Skate (Sharp-Nosed Skate): *Raja laevis*

The popular name is derived from its large size, which may attain a length of 5 feet and a weight of 35 pounds. The snout is prolonged and pointed and the body spines small. It is the only skate with pigmented mucus pores on the underside. Found from Newfoundland to Cape Hatteras.

West Coast:

4. California Skate: *Raja inornata*

The outer border of the pelvic fin is deeply concave and the color is dark olive to brown with vague mottlings. It reaches 2½ feet. Found from the Strait of Juan de Fuca in the North Pacific south to Cedros Island, California.

5. Big Skate: *Raja binoculata*

There is a large ocellar spot on the inner side of each pectoral fin. The outer border of the pelvic is nearly straight. It reaches 6 to 8 feet in length and the egg cases are a foot long and contain up to seven eggs. Found from Alaska to southern California.

6. Long-Nosed Skate: *Raja rhina*

The snout on this skate is very long and tapering. The overall size may reach 4 to 5 feet. Found from Alaska to southern California.

Electric Rays: *Superfamily Torpedinoidea*

These are very odd rays possessing an almost circular disc and a stout, somewhat sharklike tail on which are situated two large dorsal fins and a large tail fin. The eyes are small; some electric rays are even blind. The body is smooth and peculiarly flabby. The pectoral fins are thick and rather immobile, being the seat of the large electric organs, which may weigh as much as one-sixth of the total weight. Because of the fact that typical muscle nerves go to these organs, they are thought to be a muscle tissue in which the electrical properties inherent in all muscle tissue have been accentuated at the expense of the locomotory properties. They are formed of thousands of hexagonal discs piled in columns and thus look like honeycombs. The resemblance to a voltaic pile is striking. A shock delivered by these rays is really a "train" of twelve to a hundred separate pulses each of which lasts about three hundredths of a second. Voltages delivered vary from eight to 220 depending upon the size of the ray and its species. Several shocks may be delivered in succession, but each one is a little weaker than its predecessor. A rest period is needed to build up the power to its full state again. The shocking power is far less than the really dangerous electric "eel," *Electrophorus*, of South American rivers. Still, it is enough to knock down and temporarily disable a full-grown man.

The purpose of the shocking power is a matter of some mystery. Almost certainly, it is defensive, and it seems likely that it may also be offensive. Presumably, electric rays are too slow-moving to catch the fishes, such as dogfish

and flatfish, that they are known to eat. They swim feebly with sculling motions of the tail, using the stiff pectorals only sparingly, if at all.

Electric rays are among the laziest of fishes. They lie buried in sand or mud most of the time. They are found in shallow and deep waters of all temperate and tropical seas, mostly over soft bottoms. They are ovoviviparous and range in size from a foot in length to 6 feet and 200 pounds.

ELECTRIC RAYS: Family Torpedinidae

TORPEDO (ELECTRIC RAY, NUMBFISH, CRAMPFISH): *Torpedo nobiliana*

Size: Matures at 2 feet. Up to 5 to 6 feet long.

Weight: Averages 30 to 75 pounds. Up to 200 pounds.

Distribution: Both sides of North Atlantic from Nova Scotia to Cape Hatteras (rarely Cuba) and from Scotland to west Africa. Nowhere plentiful.

Identification: The disc is very wide and round and about one-half the total length. The color is chocolate to purplish brown, sometimes with obscure dark spots.

Habits: Little is known other than the general information given above. This is one of the most electrically powerful of the electric rays. It is known to eat

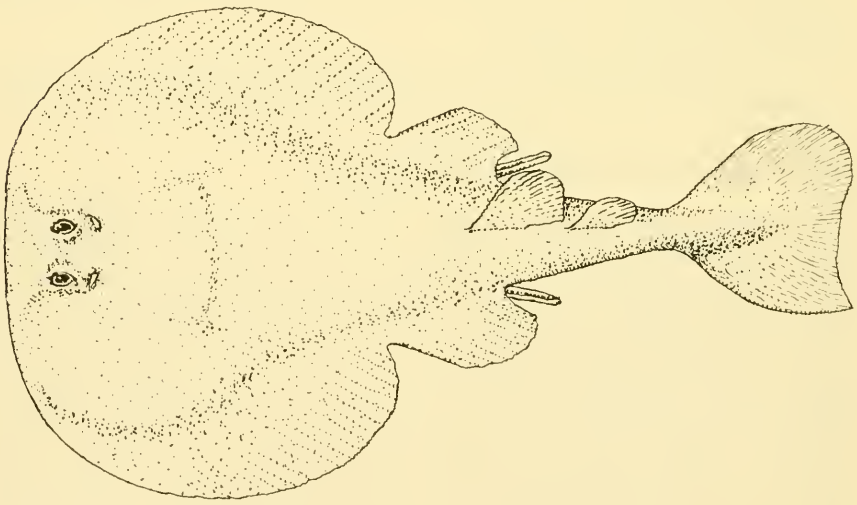


Fig. 75. Torpedo ray.

large and even active fish such as salmon, eels, and flatfishes, a support for the argument that electric rays use their electric powers to secure food.

Similar Species: The California electric ray, *Torpedo californica*, is found from British Columbia to southern California and is locally plentiful in moderate depths. It reaches a length of 3 feet and a weight of 50 pounds.

The little electric ray or crampfish, *Narcine braziliensis*, belongs to a genus of small rays which has oval discs, not nearly as blunt anteriorly as the torpedoes. They have a mottled coloration which blends with the sand, resembling the

coloration of the round sting ray. This species eats invertebrates mostly and can produce shocks of thirty-seven volts. It matures at 9 to 10 inches in length and reaches 18 inches. Found from Florida and Texas south to Brazil.

The True Rays: *Superfamily Myliobatoidea*

The remaining rays are grouped in a single superfamily. All have the tail very well marked off from the body, usually like a whip, with one or several dangerous poison spines at its base (exceptions to this are found among butterfly and devil rays). This tail spine can be a very dangerous defensive instrument which can produce excruciating pain. Known remedies are a warm Epsom salts bath or an injection of 5 per cent permanganate of potash solution (Condy's Fluid). The injection of antibiotics or other antiseptics may also be of value. These are principally shallow-water fishes of the tropics and subtropics. Some enter fresh water. The species vary in size from under a foot to 23 feet in width. They are all ovoviviparous. Several species can utter a grunting sound.

STING RAYS: Family Dasyatidae

The discs are usually rhomboid but may be round (in the round sting rays). The tail is long and whiplike and bears no fins (except for round sting rays). These rays all have a long serrate spine at the base of the tail. This spine is not only poisonous, but it is large enough to cause a dangerous wound by itself. The stingers may vary from an inch or so to over a foot long. If one is lost or worn out another grows in its place so that two or even three may be present at once. The spine appears to be used mostly in defense but may rarely be used offensively. It was a matter of debate for many years whether or not the spine actually carried a poison. It was thought that the jagged wounds, and mucus and other foreign matter introduced into the wound, were enough to cause the extreme pain, swelling, cramps, inflammation, gangrene, or, rarely, death. (Stings are not always serious, but the fact that they may be so should be warning enough.) Then it was discovered that the narrow grooves along each edge of the spine contained a glandular, poison-secreting tissue. Furthermore, the poison is of a virulent nature. Poison glands may also be present at the base of the spine.

Sting rays are usually not active, lying buried in sand with only the eyes and spiracle showing. However, they are not nearly as sluggish as torpedoes and may frequently be seen swimming over reefs and sandy bottoms, being capable of considerable speeds. They are mostly crustacean- and mollusc-eaters, but do take fishes also. They commonly stir up the bottom with their pectorals in search of food. At times they are extremely abundant over shallow, sandy bottoms, almost seeming to pave the bottom. Large ones are powerful, but inoffensive. The authors, in order to stir one very large southern sting ray for purposes of photography (*figs. 71* and *76*), grasped it by the tip of the tail. It rose, circled slowly, swam a short distance, and sank to the bottom, burying itself by throwing sand over its back with its pectoral fins. This afforded an excellent chance to observe and photograph its exceedingly graceful and beautiful "flight," not forgetting, of course, that this seemingly inoffensive beast possessed a formidable weapon. Sting rays are ovoviviparous and found in warm shallow waters the world over.

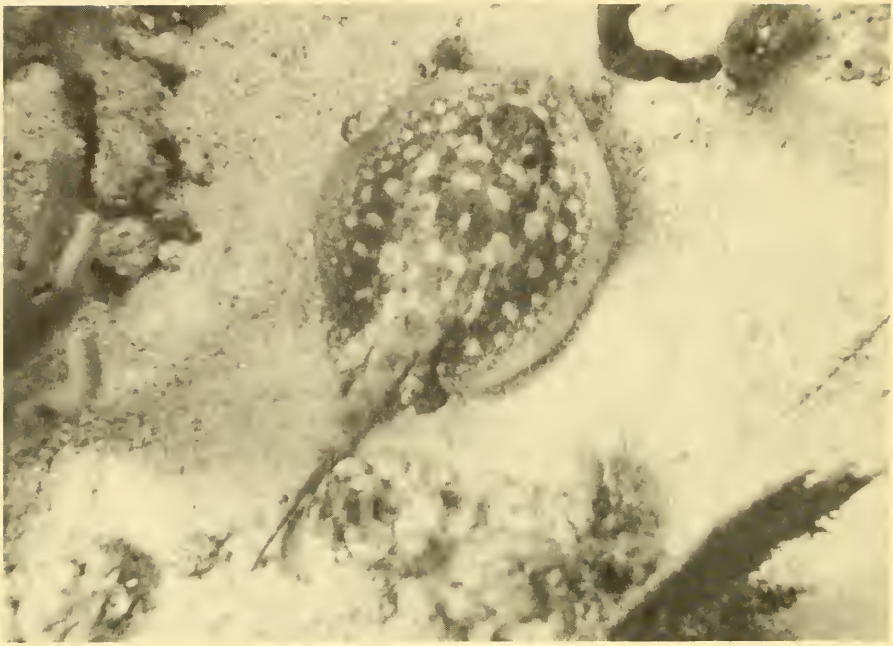


Fig. 76. Top. The round sting ray, Urolophus, *is mottled to resemble its substrate. This ray, though small, has a very powerful sting. Bottom. The southern sting ray,* Dasyatis *americana, is most easily identified by the large, finlike fold beneath the tail.*

ROUND STING RAY: *Urolophus jamaicensis*
(Also known as Urobatis)—Figure 76

Size: Usually 16 inches to 2 feet long.

Distribution: Florida to the Caribbean. Sometimes to Cape Hatteras.

Identification: The disc is round and light-colored with dark mottlings which blend in with the sandy bottom. The pattern may vary with the nature of the bottom, but this has not been demonstrated. The tail is short and has a caudal fin and highly developed spine.

Habits: This is a species of shallow shoal and reef waters. It is not timid. One swam directly under the arm of one of the authors and settled quietly on the sand not two feet in front of him. It is more common than supposed, as swimmers will surely discover, being found often about reefs in the Bahamas particularly. It scoops out holes in the sand to expose its invertebrate food. In spite of its small size, the sting is dangerous, said to be more dangerous than other sting rays of much larger size.

Similar Species: Members of this genus are common in most tropical waters. The Californian round sting ray, *Urolophus helleri*, is very similar to the eastern form and is found from Point Conception to Panama.

STINGAREE: *Dasyatis sabina*

Size: To only 15 inches across, the smallest Atlantic member of its genus.

Distribution: Gulf of Mexico to Florida and the Caribbean. To Cape Hatteras and, rarely, to the Chesapeake Bay.

Identification: The snout is pointed and rather long, and the pectorals are very rounded. It is yellow-brown to dark brown with a dark line down the midline. The midline of the back possesses prickles.

Habits: This ray is more or less strictly tropical and is found in very shallow water. When walking through shallow water, it is well to use a shuffling motion of the feet. This tends to drive the rays ahead if they are present. The sting is probably not as painful as that of the round sting ray.

Similar Species: The southern sting ray, *Dasyatis americana* (*fig.* 76), is the most common large species from Cape Hatteras to the Caribbean. It replaces

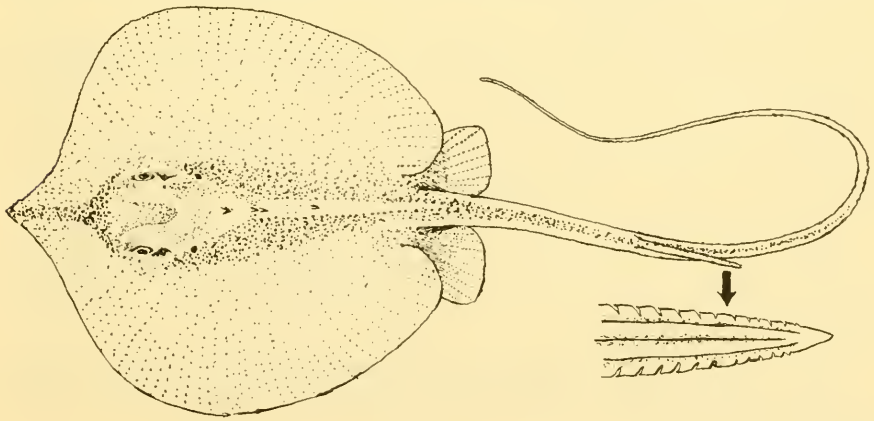


Fig. 77. Stingaree.

the northern sting ray south of Cape Hatteras and these two rays are very similar in habits. It is easily recognized by the finlike folds under the tail behind the spine, a keel above this fold on the tail, and the angular shape of the pectorals. It averages three feet across the pectorals and probably reaches 4 feet. It often enters very shallow water, at which times the pectoral fins and tail may break the surface.

The northern sting ray, *Dasyatis centrura*, reaches 13 to 14 feet in length and 5 feet in breadth. At 4½ feet in breadth, it weighs 180 pounds. It is much like the southern sting ray but has a thorny tail with no keel on top of the tail. It is locally plentiful in shallow waters from Cape Hatteras to Cape Cod.

The diamond sting ray, *Dasyatis dipterurus*, is much like the preceding species. It is found from British Columbia to Central America and is common in bays from San Diego southward. It reaches a length of 6 feet.

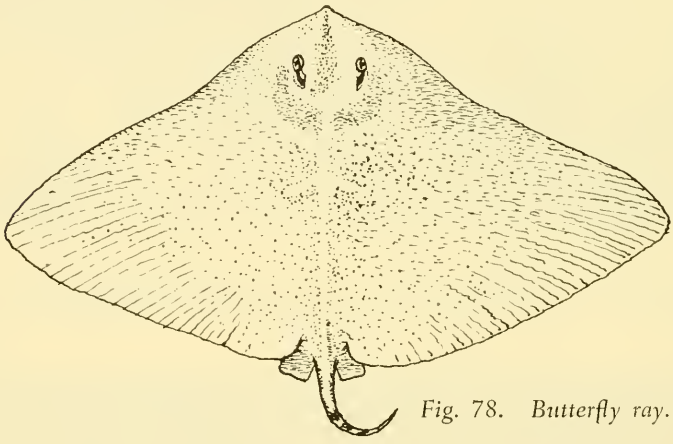


Fig. 78. Butterfly ray.

BUTTERFLY RAY (SAND SKATE): *Gymnura micrura*

Size: Averages 2 feet in breadth. To 4½ feet across, rarely.

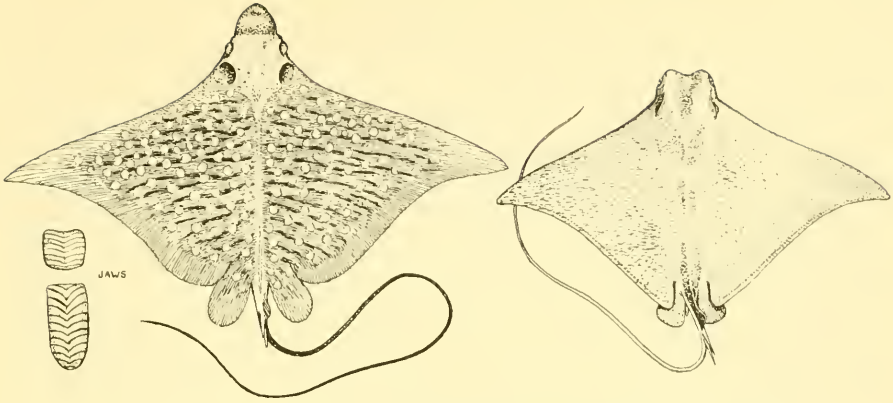
Distribution: From Massachusetts to Brazil. Most common from the Gulf of Mexico to the Chesapeake.

Identification: The breadth is much greater than the length, and the spineless tail is very short. The color is gray, brown, or even greenish or purplish. It can change its color to match the surroundings somewhat.

Habits: This ray behaves much like the *Dasyatis* species, but is more active, especially in response to tide changes. This ray prefers coastal sandy bottoms and feeds on a wide variety of molluscs and crustaceans. It may enter brackish waters. It bears young from May to August.

Similar Species: The giant butterfly ray, *Gymnura altavela*, grows to a breadth of 7 feet or more. It is found from Massachusetts to Brazil. This ray has small spines on the tail base. It is known to utter a grunting sound when in distress.

The butterfly sting ray, *Gymnura marmorata*, of Point Conception to Mazatlán, has a small sting and reaches a breadth of 5 feet. It is common in shallow bays along beaches.



Figs. 79 and 80. Spotted eagle ray (left) and cow-nosed ray (right).

EAGLE RAYS: Family Myliobatidae

These rays have largely abandoned bottom-living habits, but still feed on the bottom on hard-shelled molluscs and occasional crustaceans. The teeth are well adapted for crushing such resistant fare and are flat and like a pavement in the jaws. When feeding, they swim near the bottom in order to detect, probably by smell, the currents emitted from clam siphons. Then they dig the clams by flapping their powerful pectorals or by rooting about like a hog with their noses. When not feeding, they swim gracefully and rapidly through the water near the surface and may even leap from the water completely. They rarely rest on the bottom. Because of their active habits, these rays are not as flat as most rays. There is a definite head with an elevated crown, which has the eyes and spiracles on the side rather than on top. The body is heavy and the pectorals powerful and thick. There are one or more poisonous spines at the tail base, but these are so near the body that they cannot be used as efficiently as those of sting rays. Nevertheless, the presence of spines as well as the large size of up to 8 feet across and 600 pounds in weight should be enough to caution the swimmer that he had best not tamper with these normally inoffensive fishes. They are very hard to handle and dangerous if hooked or speared.

Eagle rays travel over deep water but are most common in sandy or muddy bays where shellfish abound. They seem not to enter enclosed bays and estuaries as sting rays do. They are ovoviviparous and found in all warm temperate and tropical seas.

SPOTTED EAGLE RAY (SPOTTED DUCK-BILL RAY, LEOPARD RAY): *Aëtobatus narinari*

Size: Averages 3 to 4 feet across. Up to almost 8 feet across.

Weight: Up to 500 pounds or more.

Distribution: Almost cosmopolitan in warm seas. North to North Carolina (rarely the Chesapeake) and over much of the Indo-Pacific.

Identification: The vivid light spots on the dark olive, brown, or black background form a distinctive pattern. The snout is almost like a duck's bill.

Habits: These large and spectacular rays are almost exclusively mollusc-eaters. They travel singly, in pairs, or in large schools of hundreds of individuals. A

large school in an oyster bed can very well spell the end of almost the entire bed. Large rays are able to crack thick-shelled molluscs, an indication of the immense power of their jaws. But the jaws are delicate as well as powerful since the meat of the molluscs is separated from the shell so skillfully that very little shell is swallowed. These are powerful swimmers and are known to leap from the water. One specimen only a little over 5 feet across was easily able to drag a 22-foot boat containing three men. They are known to emit a harsh cough when captured. The young are released into the air one at a time by the mother as she leaps out of the water, a spectacular method of childbirth which is seldom observed.

Similar Species: The eagle ray, *Myliobatus freminvillei*, is smaller than the spotted eagle ray, reaching 5 feet across, and maturing at 2 to 3 feet across. There are no spots, and the snout is not like a duck's bill. It strays to Cape Cod in summer, but lives the year round in the Caribbean.

The bat sting ray, *Myliobatis californicus*, is very similar to the eagle ray and is common inshore in bays from Oregon to Magdalena Bay.

COW-NOSED RAY: *Rhinoptera quadriloba*

Size: Averages 3 feet across. Up to a width of 7 feet.

Weight: Averages 25 to 70 pounds.

Distribution: New England. Less common in tropical than in warm temperate zones of both hemispheres.

Identification: The peculiar bilobed nose is distinctive. The color is a yellowish brown.

Habits: This is the commonest of the eagle rays. Like the rest of them, it is a mollusc-eater. A school of these rays rooting about in clam or oyster beds is reminiscent of a drove of hogs. It is commonest in shoal water and may leap from the surface. The young are produced in spring and summer. Little is known of their habits in spite of their reasonable plentifulness. Cow-nosed rays have the disturbing habit of "rounding" a swimmer, but in doing so have no aggressive intentions.

DEVILFISHES: Family Mobulidae

These rays have completely abandoned the bottom-living habit and do not even feed there. Thus, the eyes are on the side of the head, and the spiracles are so reduced that respiration is sharklike, most water entering the gills through the mouth. Devilfishes are easily identified by the large cephalic fins that look like devil's horns on either side of the mouth. These are used to funnel and scoop plankton and small fishes into the ray's mouth. A gill sieve filters the food from the water much as in the whale and basking sharks. There are no poisonous tail spines, but the great size and famed power of these fishes should be enough to caution the unwary. Contrary to rumor, these are inoffensive fishes showing little fear of man. Rarely are we treated to a sane view of the manta, for instance. Magazines and movies would rather show them gushing blood from harpoon wounds or making alleged attacks on swimmers. If molested, however, one can hardly blame them for fighting back. The pectoral fins are used to deliver repeated sledge-hammerlike blows. Devilfishes are ovoviviparous and found in all temperate and tropical seas.

LITTLE DEVILFISH: *Mobula hypostoma*

Size: Up to 4 to 5 feet in width. Near relatives reach 23 feet in width.

Weight: Up to 40 pounds. Near relatives reach 3,500 pounds.

Distribution: Cape Hatteras to Brazil. Recorded north as far as New York.

Identification: The mouth is on the underside beneath the short snout. The color is a blackish brown. The tail is relatively long.

Habits: Little devilfish travel in schools and feed by rushing at schools of small fishes or plankton. They drive the prey toward shallow water near shore and may even beach themselves temporarily in their vigorous feeding rushes. They are inveterate leapers. According to Coles (1916) these rays leap clear of the water and land with a great splash. The larger manta also leaps, but usually not completely clear of the water. Females also leap during childbirth. The young are ejected one at a time as the female leaps into the air. If a female devilfish is harpooned, this will often cause a forcible ejection of the young. Little devilfish can utter a musical barking sound.

Similar Species: The lesser devilfish, *Mobula lucasana*, reaches 7 feet in width and is found from Baja California to Central America.

The manta, *Manta birostris*, has a large mouth terminal on the snout and a shorter tail than the little devilfish. It ranges in all tropical and subtropical seas and is fairly common. It reaches 23 feet in breadth and 3,500 pounds. Contrary to the similar little devilfishes, it usually travels alone, moves slowly as it feeds, and leaps only partly out of the water. It still makes a tremendous noise in its leaps however. Tales of its power in pulling boats are legendary. It likes to bask

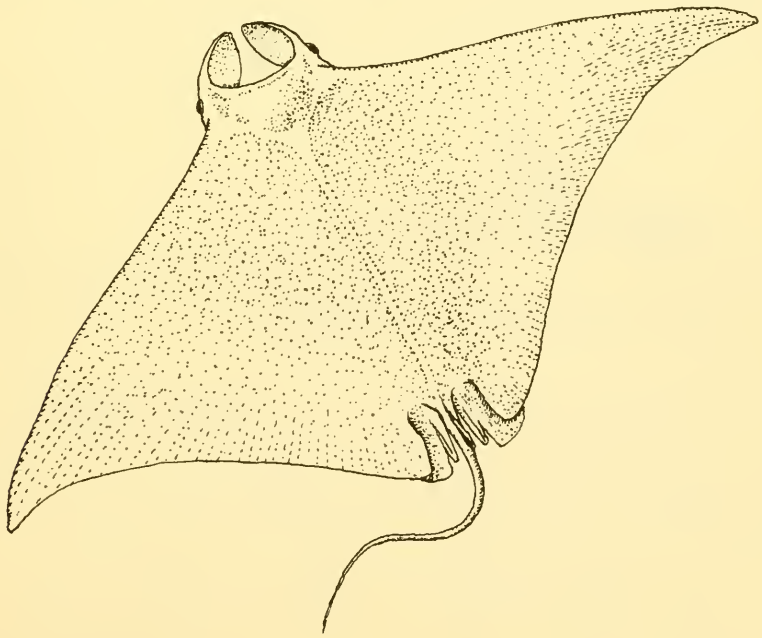


Fig. 81. Little devilfish.

in the sun with the upturned "horns" protruding from the water, at which times it is easily approached. The word "manta" means "blanket" in Spanish.

CHIMAERAS: Class Chondrichthyes, Subclass Holocephali

These very odd fishes are mostly found in the deep sea and have the long, pointed tail that is characteristic of so many deep-sea fishes. The reason for this is unknown. Chimaeras do not seem to use the tail much for propulsion, this task mainly being the job of the flapping pectorals. Very commonly there are odd appendages on the head of the male which may be of some unknown reproductive function. They have an operculum like bony fishes. Despite their preference for deep waters, chimaeras do get into shallow water. The long dorsal spine is to be avoided. It is poisonous and able to inflict a painful wound.

CHIMAERAS: Family Chimaeridae

RATFISH (CHIMAERA): *Hydrolagus colliei*

Size: To 3 feet.

Distribution: Northwest Alaska to Baja California. Fairly common in shallow water in northern California and northward.

Identification: The color is silvery with gold, blue, and green iridescent sheens.

Habits: The egg cases are unique. Very little is known of the habits. Presumably, ratfishes eat invertebrates, as the chisellike front teeth and crushing back teeth would indicate.

Similar Species: The Atlantic chimaera, *Chimaera affinis*, reaches 3 feet and is a deep-water fish of waters to the north of Cape Cod.

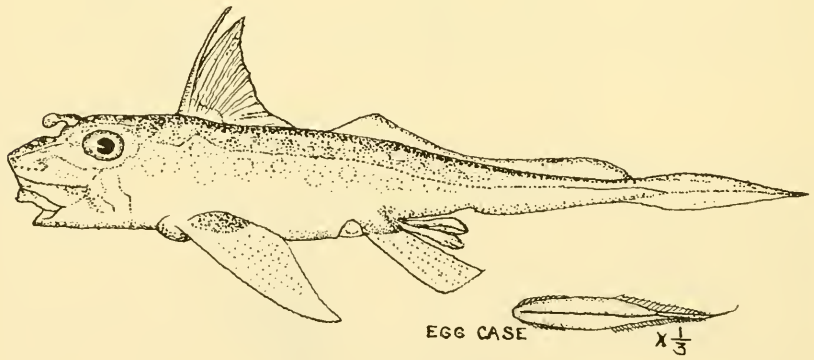


Fig. 82. Ratfish.

CHAPTER 9

MASTERS OF THE WATER—Bony Fishes

CLASS OSTEICHTHYES (*"bony fish"*)

We have previously mentioned that the primary aims of this book are to give identification of groups (such as families) rather than of species and to see into which niche each group falls in the economy of the sea. Perhaps nowhere is the usefulness of this procedure better exemplified than in the case of bony fishes, for the following reasons:

1. Bony fishes are the dominant animals of the sea, receiving far more attention than any other of the sea's inhabitants. They are tremendously numerous and, in contrast to the sharks and rays, extremely diverse both in form and habits. To understand this great diversity, it is best to think not in terms of thousands of species, but in terms of families.
2. By keeping groups in mind, the swimmer will not be completely lost when confronted by strange, new fishes elsewhere in the world. For instance, both the red tai of Japan and Europe's huge dentex become species of porgies, Sparidae, rather than just a couple of unknown, isolated species.
3. The bony fishes are much more difficult to identify than sharks and rays, demanding the use of comparatively complex characters for proper identification. For instance, demoiselles, Pomacentridae, are not too difficult to identify as a group, but species identification is complex and is still a matter of dispute among ichthyologists.

It is difficult, if not impossible, to give a list of characters that strictly define bony fishes. All have skulls that are composed of a complex system of bones, but this information is of little use to the underwater swimmer. However, there are two field characters which vary little; the possession of an operculum which covers the gills (if absent, as in some eels, there is never more than one gill opening) and the presence of fins which are supported by bony rays. The fins are very mobile, in contrast to those of the cartilaginous fishes. Usually, also, there is a covering of bony scales which overlap like the shingles on a roof.

The movement of fishes is a topic of great interest, to which the observations of the underwater swimmer can add much. The flight characteristics of birds

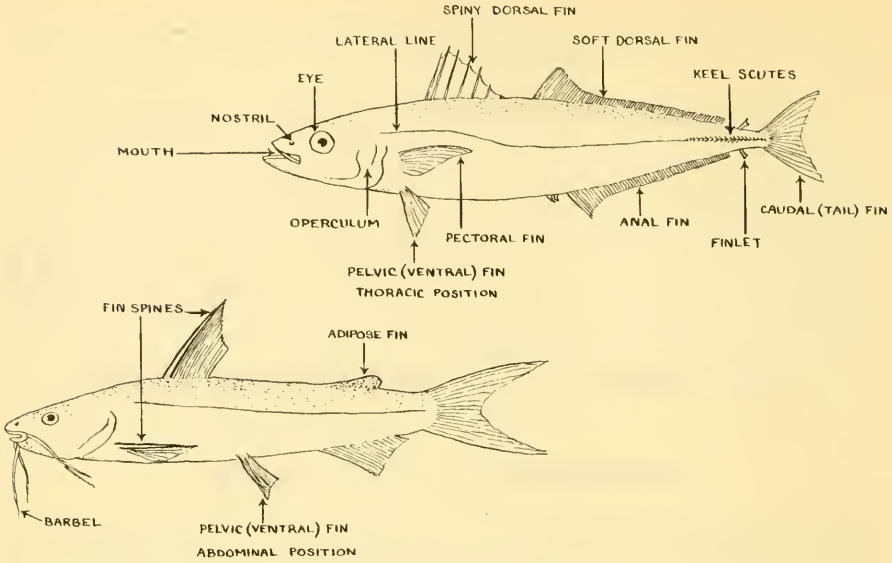


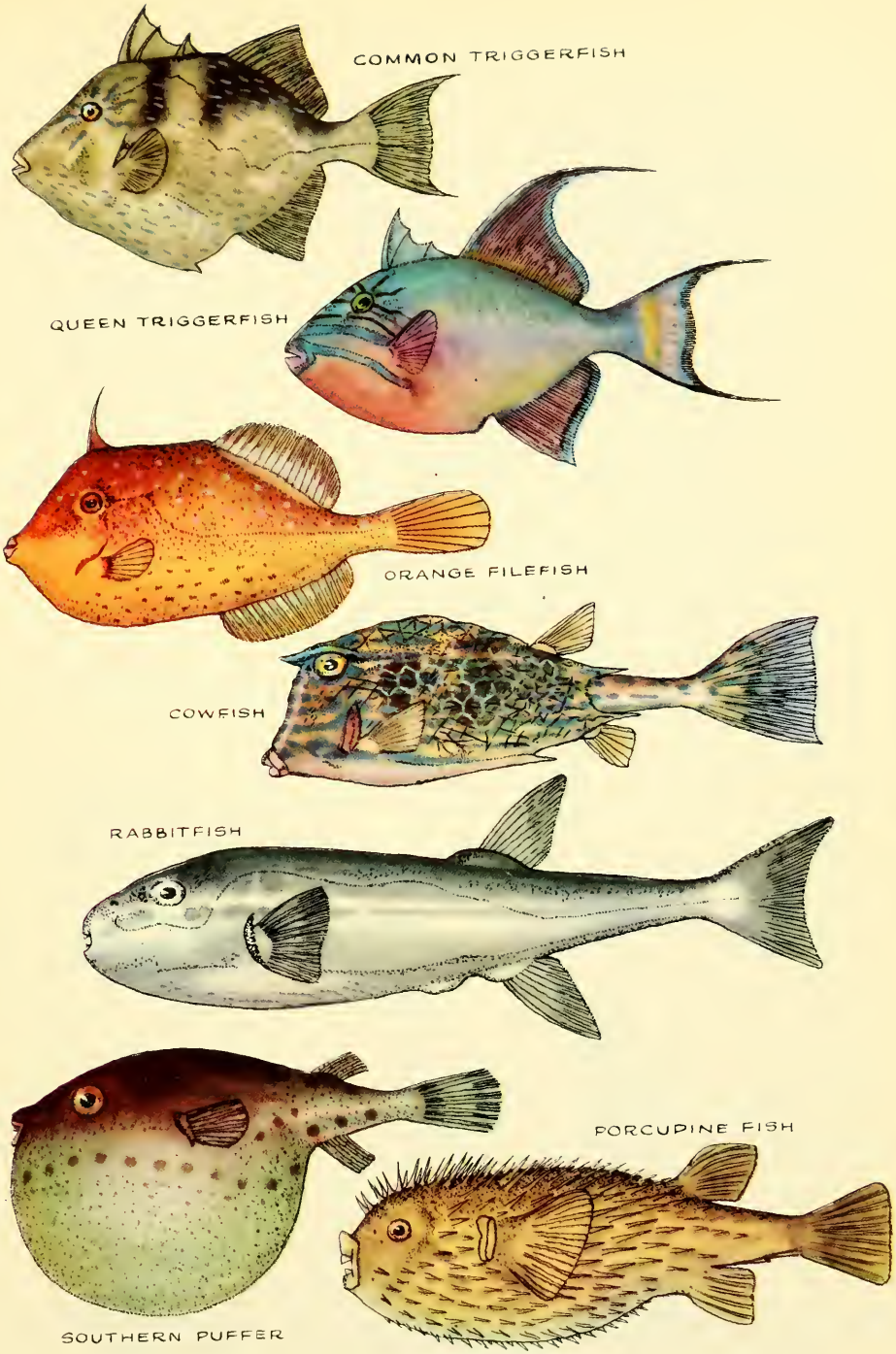
Fig. 83. External anatomy of bony fishes.

through their medium, air, have been well studied, but fish movement is less understood, though they, too, fly, in a sense, through water. Bony fishes are more efficient swimmers than sharks and rays because of the combination of three factors: (1) the shortened, compact body allowing short, efficient, lateral strokes of the tail (a tendency seen in the mackerel sharks), (2) the possession of an internal hydrostatic organ, the swim bladder, which adjusts the specific gravity of the fish so that stabilization in any depth of water is possible (sharks, as we pointed out earlier, cannot do this), and (3) the great mobility of the fins, resulting in increased maneuverability, and the ability to start and stop suddenly (sharks and rays cannot do this). Fish movement is so intimately related to the habits of fishes and is so useful in identification of groups that we will give it considerable attention in our review of the families.

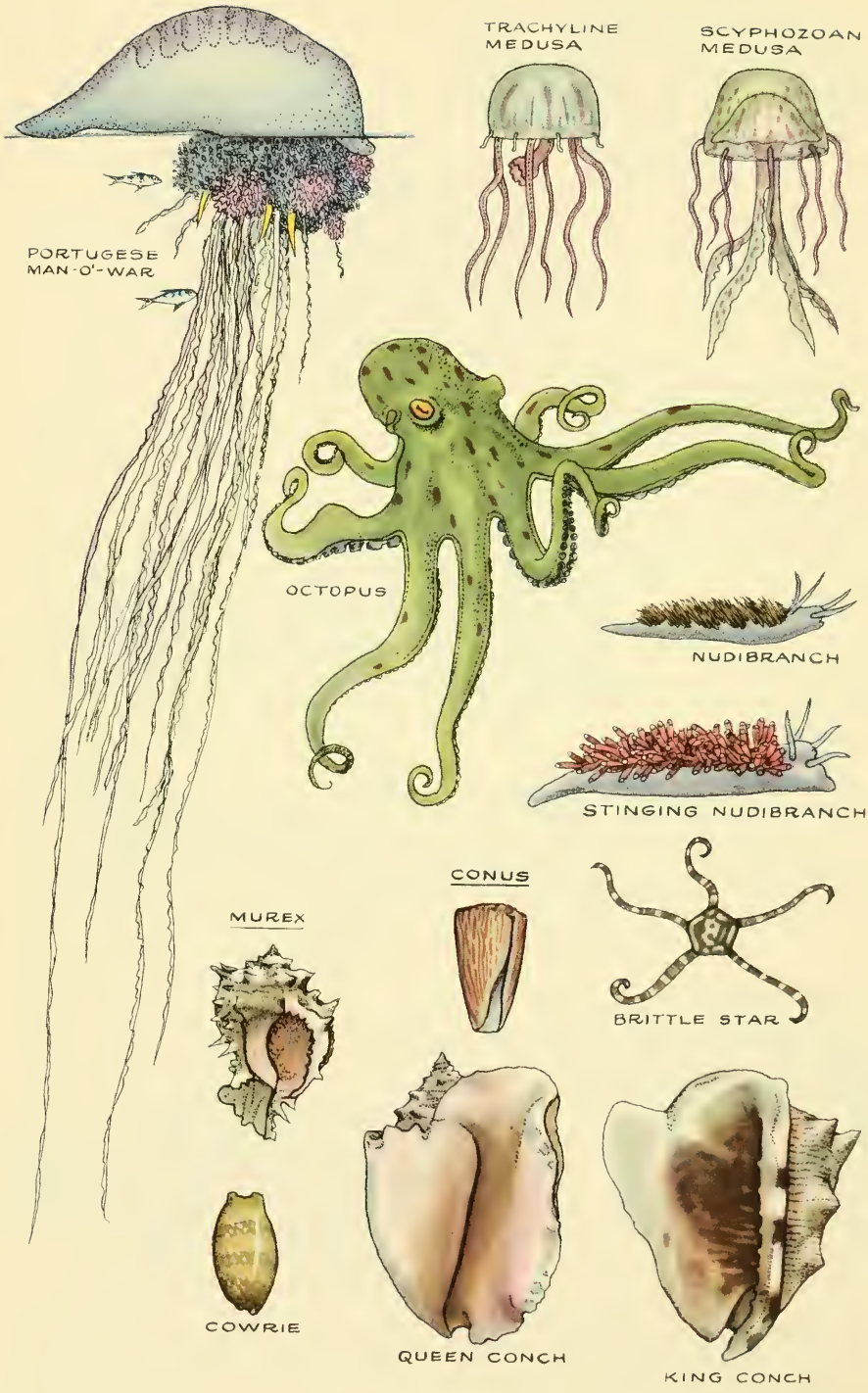
Breder (1926) has set up three main categories of fish movement:

1. Carangiform (like the jack, family Carangidae). The typical fish movement in which propulsion is accomplished by short lateral strokes of the tail, and steering is accomplished largely by the paired fins.
2. Anguilliform (like the eel, family Anguillidae). The long-bodied fishes such as eels progress by a long series of sine waves which pass down the body. (Most sharks, being long-bodied, have a modified and shortened movement of this type.)
3. Ostraciform (like the trunkfishes, family Ostraciidae). Propulsion becomes largely a task of the pectoral, dorsal, and anal fins. The tail is used mainly for steering.

Within these very broad categories many variations occur, and these shall be mentioned as they are met, particularly as departure from the typical



COLOR PLATE 9



COLOR PLATE 10

carangiform movement is made. Carangiform movement is an adaption for speed. Just how fast fishes can travel is not well known. Some tuna and spearfishes probably can travel over 40 mph.

The various senses are as highly developed in bony fishes as in sharks and rays, but the emphasis is on the eye rather than on the nose. As in sharks and rays, the lateral line serves to detect water vibrations. Taste is well developed and hearing is somewhat less so. Barbels about the mouth, when present, are delicate taste organs used for detecting food. The nervous system is developed to a fairly complex degree as compared with invertebrates. Groupers can be trained to follow a swimmer who has fed them a few times and, in fact, can be a nuisance. The social behavior of fishes is complex and a huge topic in itself. Some fishes are known to perform extraordinary migrations (many mackerels and eels) and others have complex courtship behavior (demoiselles, wrasse, gobies, blennies, and possibly grunts), but most piscine social behavioral patterns remain unknown.

Most marine fishes lay large numbers of pelagic or adhesive eggs. Some, such as demoiselles, build nests. Only a few bear living young as do most sharks and rays.

Bony fishes exhibit a wide range of colors. Many of them are able to change their colors greatly and rapidly. Color change is accomplished by the expansion of pigment-bearing cells in the skin. These cells are called "chromatophores" and are under both nervous and hormonal control (pituitary gland). A spectacular color and pattern control is known for flatfishes, where agreement of color with the surroundings is remarkable. It is even possible for these fishes, if placed on a checkerboard, to assume the checkerboard's pattern. Many fishes exhibit several color phases which confuse identification.

Color and body form may differ strikingly in young and old fish of the same species. A well-known example is the black angelfish in which the young are striped and the adults are not (*Color Plate 7*). The underwater swimmer, however, is very likely to see, especially about coral reefs, many small, oddly shaped, brilliantly colored fishes that are hard, if not impossible to identify. These are the young of reef species, and it must be admitted that very little is known of them.

These several topics—motion, the senses, social behavior, food, color variation, and change of form during growth—merely touched on here, offer almost unlimited opportunities for observation and study. In this age, when man is constantly expanding his numbers and activities, the sea is assuming a vital importance, and bony fishes are, perhaps, the chief reason for this because of their value as food.

THE PRIMITIVE BONY FISHES: Subclass Chondrostei (*"cartilage bone"*)

Ancient chondrosteians possessed bone, but the modern ones, the sturgeons, have skeletons of cartilage. These huge fishes are possibly the largest of bony fishes. They are toothless, bottom-feeding, sluggish, and reminiscent of sharks both in movements and form. The tail is asymmetrical, with a longer upper lobe (heterocercal), and there are five rows of large bony plates along the body.

Their food is detected with the barbels on the snout and is strained from mud and soft bottoms with the protractile mouth. The name "sturgeon" is derived from a German word meaning "to rummage around." Sturgeons are found in the seas and large rivers of Eurasia and North America. Like salmon, they spend most of their lives in the sea, entering fresh water to breed. The flesh and roe (caviar) are prized as food.

STURGEONS: Family Acipenseridae

SEA STURGEON (COMMON STURGEON): *Acipenser sturio*

Size: Rarely over 8 feet. Recorded up to 18 feet.

Weight: Recorded up to over a ton.

Distribution: From the St. Lawrence River to the Carolinas. Most common about the Chesapeake Bay. Also found in European waters.

Identification: Separated from other smaller sturgeons by the shape and number of dorsal plates (scales).

Habits: Because of the value of this large fish and the pollution of so many of our large rivers, it is much reduced in numbers. In spite of its clumsy build and sluggishness, a sturgeon is capable of bursts of speed. The lateral scutes on the tail are used as weapons and can cause serious cuts. Sturgeons are known to leap from the water upon occasion, a peculiar show of energy for so sluggish an animal. In May, the adults ascend rivers to spawn, as many as two or three million eggs being produced by a single female. Isinglass used to be made from the swim bladders of sturgeons.

Similar Species: The white sturgeon, *Acipenser transmontanus*, is a West Coast species found from Alaska to Monterey Bay. It enters large rivers, such as the Sacramento, Columbia, and Fraser, to breed. It is comparable in size and habits to the Atlantic species. Formerly thought to be worthless, demands for its flesh have made it rare and it is strictly protected by law.

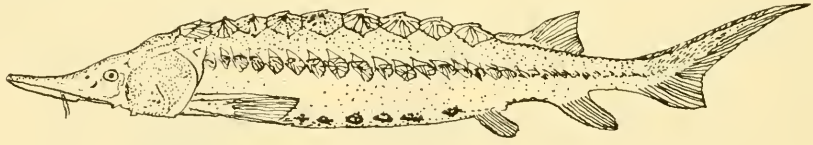


Fig. 84. Sea sturgeon.

THE MODERN BONY FISHES: Subclass Teleostei (*"true bone"*)

The vast and imposing array of modern bony fishes can be best considered as falling into five orders as follows:

1. Isospondyli, primitive forms with the ventral fins on the belly and no spines in the fins (herrings, trapons, salmon, etc.).
2. Apodes, the eels.
3. Ostariophysi, primarily fresh-water fishes, of which only the catfishes will concern us.
4. Mesichthys, or "middle fishes," a collection of several groups thought to

be a transition from the isospondylous type to the acanthopterygian type (killifish, flying fish, sea horse, etc.).

5. Acanthopterygi, fishes which have the ventral fins up under the pectorals or chin, the pectorals high on the sides, the body compact, and spines in the fins (perches, mackerels, flatfishes, etc.).

The evolution of the bony fishes is not at all clear. As in sharks and rays, silhouette, placement and form of the fins, and habits are important in identifying them.

Herringlike Fishes: *Order Isospondyli*

The fin rays are all soft and the pelvic (ventral) fins are placed far back on the belly. The pectoral fins are placed low on the body and the tail fin is forked except for a few species in which it is square (Salmonidae). All the rest of the bony fishes probably descended from members of this order. In spite of their relative primitiveness, members of this group are vastly important. The tarpons, bonefishes, salmons, and trouts are among the gamest, if not the gamest, of all game fishes and without them, fishing, the world's most popular sport by far, might not be as popular as it is. The herrings, sardines, menhaden, and a host of others are vitally important for both the economy of the sea and the economy of man.

TARPONS: Family Megalopidae

These brilliant silver fish are among the largest of this suborder. Anyone who has seen one under water has experienced one of the greatest thrills of underwater swimming. The huge scales, large enough to be used as jewelry and ornaments, seem to catch and reflect every possible glint of light as the powerful tail propels the fish silently and swiftly through the water. The undershot jaw, the large size, and the shape of the dorsal fin serve to identify the single species.

TARPON (GRANDE ECAILLE, SABALO, SILVER KING): *Tarpon atlanticus*

Size: Up to 8 feet. Averages 5 feet.

Weight: Up to 350 pounds. Averages 50 pounds.

Distribution: Cape Cod to Brazil. Chiefly in the Caribbean, off Florida, and in the Gulf of Mexico.

Identification: Same as for the family.

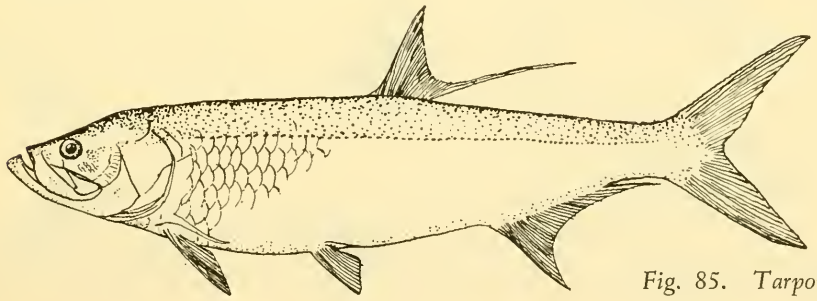


Fig. 85. Tarpon.

Habits: This greatest of all game fishes is mainly an inhabitant of shallow waters along channels, flats, mangroves, and estuaries. It pursues small fishes with great vigor chiefly at night and also eats crustaceans. It migrates north in the warm months, but is very sensitive to cold. In its leaps from the water the posterior filament on the dorsal fin is used to determine the direction of the fall. Tarpons can leap 8 to 10 feet vertically from the water or 20 feet horizontally, and these leaps have sometimes resulted in injury to innocent bystanders. One knocked a man from a boat, so stunning him that he drowned. Another landed on a man's neck, breaking it. Tarpons are immensely prolific, producing millions of eggs. The young larvae look very different from the adults, being band-shaped and transparent (probably for protection) and like eel larvae. Adults are usually solitary but may also school.

TEN-POUNDERS: Family Elopidae

These, like tarpons, are bright silvery fishes, but they are slender and have the ventral fins slightly anterior to the dorsal fin. The one species is cosmopolitan in warm seas.

TEN-POUNDER (LADYFISH, CHIRO): *Elops saurus*

Size: Up to 3 feet.

Weight: Averages 1½ to 5 pounds. Up to 15 pounds.

Distribution: Florida to the Caribbean. Straggles to Cape Cod. Gulf of California to Mexico. Also in the Salton Sea of California.

Identification: Same as for the family.

Habits: Like the following bonefish, the ten-pounder is primarily a fish of shallow water which comes inshore over soft bottoms with the tides to feed upon small fishes and crustaceans; it may even enter fresh waters. The young

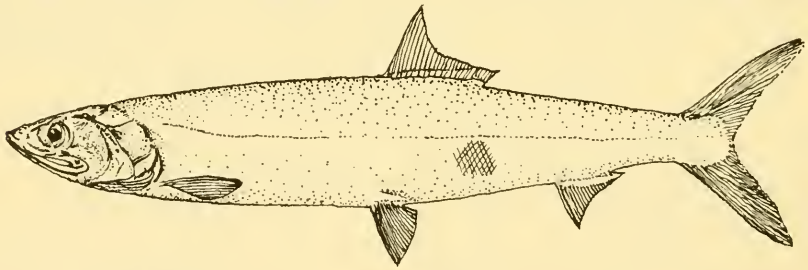


Fig. 86. Ten-pounder.

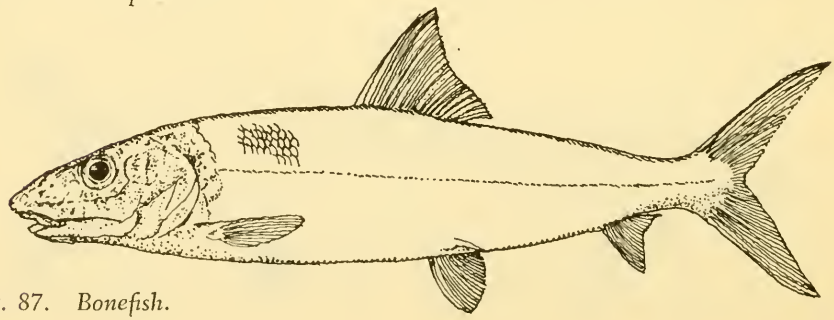


Fig. 87. Bonefish.

are band-shaped and transparent, 2 to 3 inches long, and are frequently thrown upon beaches by the waves, known locally as "ghost fishes." This is a schooling species and is occasionally found over deep waters.

BONEFISHES: Family Albulidae

These are, like the two previous species, brilliant, silvery, and game species. There is but one species of cosmopolitan distribution in warm seas. The bonefishes have a mouth under a piglike snout. The dorsal fin is large, high, and in advance of the ventrals, and the body is stout.

BONEFISH (LADYFISH, BANANA FISH): *Albula vulpes*

Size: Up to 3 feet.

Weight: Averages 2 to 5 pounds. Up to 16 pounds.

Distribution: The tropics north to Florida and San Diego. Rarely north to Cape Cod and Monterey Bay.

Identification: Same as for the family.

Habits: As is suggested by the position of the mouth, this is a bottom feeder, apparently the only isospondylous fish that is. It comes inshore in shallow water with the tide to feed over sand or mud on small fish, crustaceans, and worms. It is extremely fast and wary. The Latin name means "whitish fox." It is usually solitary but schools when small, and is sought after as a game fish, there being few fish that are harder to hook and land. Like the two former fishes, it also has transparent, bandlike, larval young, and like the ten-pounder, these young are sometimes thrown ashore in great numbers.

The underwater swimmer will be lucky to see a bonefish and will need all the skill and stealth at his command to approach one, for the least disturbance will send it off at high speed. Bonefish are kept only with difficulty in aquariums. Slight disturbances by spectators send them smacking into the walls of their tanks in efforts to escape.

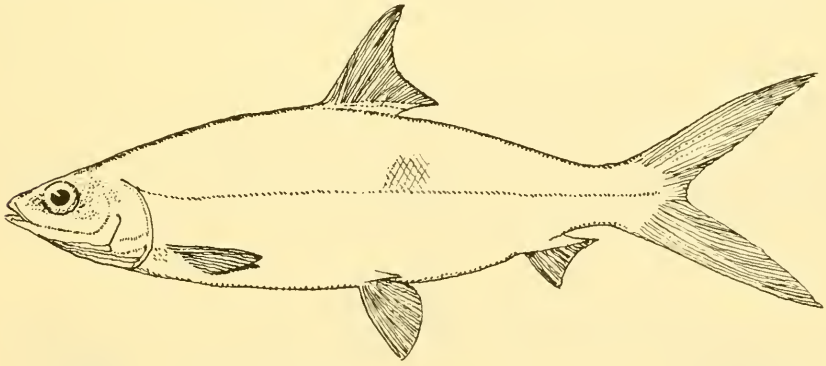


Fig. 88. Milkfish.

MILKFISHES: Family Chanidae

This is the fourth and last of the large, brilliant, silvery, game, isospondylous fishes of North America. The body is spindle-shaped and compressed, and the

tail is very large. There are no teeth in the mouth. The single species of this family is widely distributed in the tropical Pacific.

MILKFISH (SALMON HERRING, AWA, WHITE MULLET): *Chanos chanos*

Size: Up to 5 feet.

Weight: Averages 7 pounds. Up to 30 pounds.

Distribution: Abundant in the Gulf of California, northward to San Francisco. Over the whole tropical Pacific.

Identification: Same as for the family.

Habits: This is a schooling, vegetarian, surface feeder. It may enter harbor mouths and inlets and is also found over deep water.

HERRINGS: Family Clupeidae

If any one group of the sea's inhabitants were singled out as being most vital to man, this one would be chosen. Whole nations quite literally would be bankrupt were it not for species of this family. But more important than their importance to man is their vital position in the sea. Most of them serve as the link in the food chain from plankton to the larger carnivorous animals, such as tuna, shark, diving birds, and seals.

The herrings, almost without exception, travel in huge schools, usually at sea near the surface but also close inshore. They have feeble teeth and long gill rakers as befits their plankton-feeding habits. The predominant color is silver tending to be greenish and bluish on the back. There is little pattern if any. The body is usually compressed, and the belly is frequently sharp-edged, bearing a ridge of sharp scales. There is never a lateral line, and the tail is always deeply forked. Herrings are exceedingly numerous in all seas and many species are difficult to identify.

COMMON HERRING: *Clupea harengus*

Size: Averages 1 foot or smaller. Up to 1½ feet.

Distribution: All of the North Atlantic. Common north of Cape Cod. Straggles south to Cape Hatteras.

Identification: The shape is distinctive. The color is dull silver with a bluish back. The sharp-edged belly scales are not strong.

Habits: This is the most numerous fish of the Atlantic and also perhaps of the world. It is a plankton feeder, but will pursue small fishes and invertebrates. Huge quantities of herring are caught both by man and by the larger carnivorous fishes. Small ones are packed and sold as "sardines." Schools of herring are

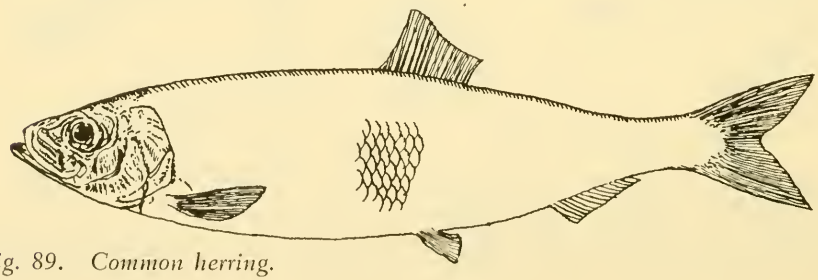


Fig. 89. Common herring.

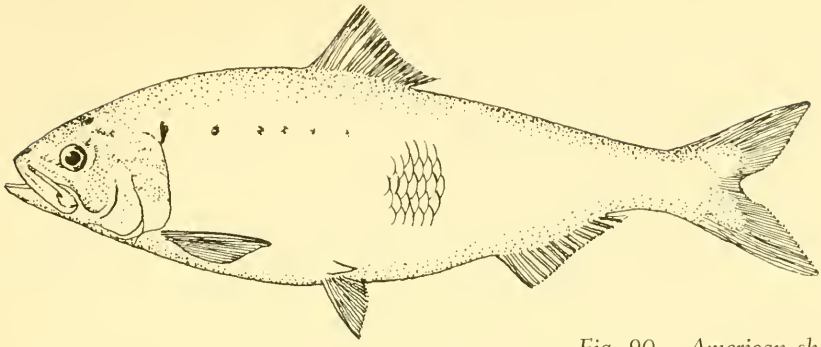


Fig. 90. American shad.

gigantic, composed of millions or billions of individuals. Herrings are fall spawners. A female lays thirty thousand or more heavy, adhesive eggs in shallow water, where they adhere to the bottom and to plants.

Similar Species: The Pacific herring, *Clupea pallasi*, is very similar to the Atlantic species. It is found south to San Diego. The Spanish sardine, *Sardinella anchovia*, is one of several true sardines found in the temperate and tropical Atlantic. It is like a small edition of the common herring.

AMERICAN SHAD: *Alosa sapidissima*

Size: Males average 14 to 18 inches. Females average 18 to 24 inches. Up to 30 inches.

Weight: Males average 3 to 4 pounds. Females average 3 to 6 pounds. Up to 12 pounds.

Distribution: In or near rivers and river mouths from the St. Lawrence to Florida. The shad was the first exotic fish to be introduced on the West Coast (1871) and is now found from Alaska to southern California.

Identification: It has a deep silvery body, a blue-green back, and a prominently notched upper jaw into which the lower jaw fits. There is a row of spots on the upper back.

Habits: This is the most delicious of the herrings and its roe is a delicacy. The shad runs up rivers to spawn when the water is 56° Fahrenheit or more (January to June, depending on location) and produces up to 156,000 eggs though the usual number is 30,000. The shad feeds on plankton. It has become much diminished in numbers because of pollution and overfishing. The location of shad at sea during the nonbreeding season is something of a mystery.

MENHADEN (MOSS-BUNKER): *Brevoortia tyrannus*

Size: Averages 1 foot to 18 inches.

Distribution: Nova Scotia to Brazil. Numerous from New England to Florida, being the most abundant fish in that range.

Identification: The head is very large for a herring. There is a series of spots behind the operculum.

Habits: This is not a good food fish but is used extensively as fertilizer and as a source of oil. Menhaden are exclusively plankton eaters and the gill rakers are extremely fine. Schools of menhaden form one of the staples in the diets of

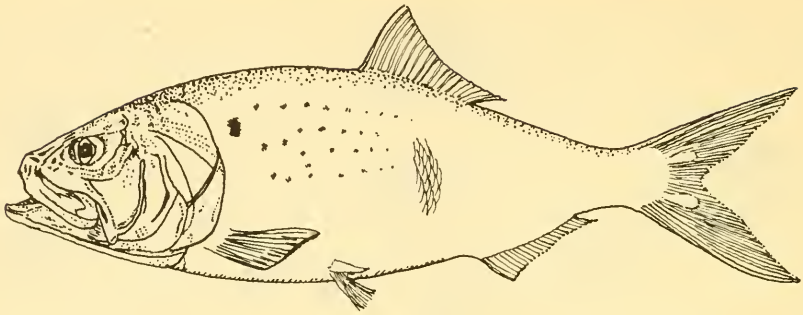


Fig. 91. Menhaden.

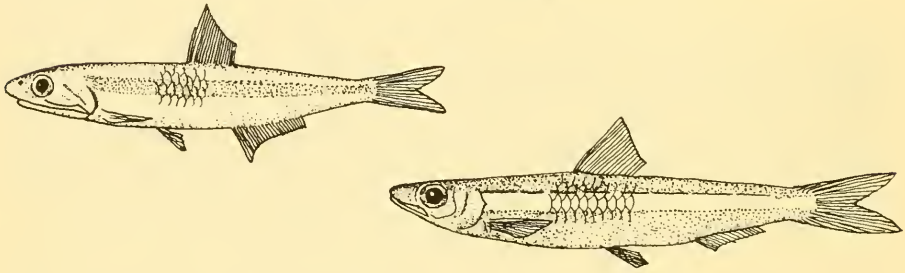


Fig. 92. Striped anchovy (above left) and green fry (below right).

sea birds and many fishes. In response to the great stress put on them by many animals including man, menhaden are very prolific and deposit up to 150,000 floating, pelagic eggs.

TRUE ANCHOVIES: Family Engraulidae

The mouth is exceedingly large and under a pronounced snout. There is almost always a wide lateral silvery stripe. The size is under 8 inches. The species are very plentiful in all warm seas. Like the true herrings, these are schooling plankton feeders of both open seas and waters near shore. They form a basic food for many fishes.

STRIPED ANCHOVY: *Anchoviella epsepus*

Size: Up to 6 inches. Usually smaller.

Distribution: Cape Cod to Uruguay. Most abundant in Florida and the West Indies.

Identification: There are many species of anchovies, all very similar. No attempt is made here to separate them.

Habits: This is one of the densely schooling, little silver-sided fishes which stream through tropical and temperate waters in endless lines. When so moving, it is very difficult to tell them apart from similar but quite distinct little fishes, such as silversides (Antherinidae) and green fry, *Jenkinsia,* which they superficially resemble and with which they frequently school. It is a unique experience to swim into a cloud of these fishes, all of which seem to be purposefully running off for some unknown appointment. They are common in

shallow water and spawn in the summer. They form a staple food for fish-eaters like mantas and gars.

Similar Species: The green fry, *Jenkinsia lamprotaenia,* is a small-mouthed greenish member of the herring family which schools densely, sometimes with anchovies, in tropical waters.

SALMON AND TROUT: Family Salmonidae

This well-known family is chiefly characteristic of fresh water of the north temperate and arctic zones, and all of its species at least breed there (with the exception of the closely related deep-sea viper fishes). A few of the larger ones, however, spend most of their lives at sea, where their migrations and habits are poorly known. Salmons and trout all have large mouths armed with powerful teeth. The bodies are elongate, powerful, not much compressed, and bear a small adipose (fatty) fin between the dorsal fin and the tail. Silver is the predominant color, but there are beautiful red, green, and blue iridescences that make these fishes very striking.

The name "salmon" was first applied to the Atlantic species, which is actually a large trout, genus *Salmo.* The true salmons, genus *Oncorhynchus,* are all of the North Pacific. Nevertheless, species of both genera have very similar habits and will be considered as a unit. Most live predaceous, fish-eating lives in the sea (some of the species are plankton feeders) until they mature at an age of about 3 to 5 years. Then, in the spring or summer, depending upon the location and the species, they begin their fabled trek up the streams. The males become grotesquely hook-jawed, humpbacked, and reddened, and the females become heavy with roe. They lay several thousand eggs in shallow riffle areas. Then the parents die exhausted, thin, and covered with fungus-infested wounds (*Salmo* species do not die after spawning). One cannot help marveling at this life-giving, yet still hugely destructive, process as one surveys the literally thousands of pounds of highly aromatic, dead fish which line the breeding streams after spawning is complete.

Descriptions and distributions follow. Coloration is given for the species when at sea; in fresh water it is much redder.

GENUS ONCORHYNCHUS

Spawns only once. Mouths black inside. Head large. Long anal fin with twelve to nineteen rays.

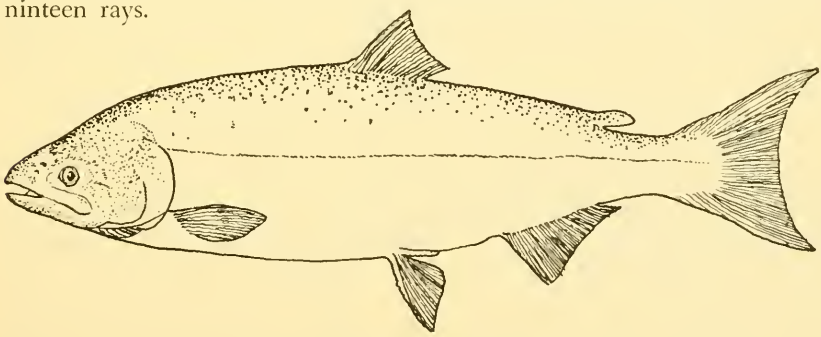


Fig. 93. King salmon.

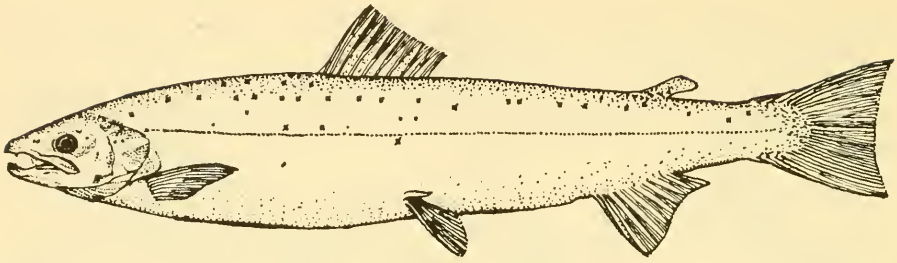


Fig. 94. Atlantic salmon.

KING SALMON (CHINOOK SALMON): *Oncorhynchus tschawytscha*

Size: Averages 3 feet. Up to 5 feet.
Weight: Averages 20 to 30 pounds. Up to 125 pounds.
Distribution: Ventura River, California to Alaska and Kamchatka.
Identification: The color is silvery with small black spots on back, dorsal fin, and caudal fin. The flesh is red or white and, though preferred red for canning, is thought by many Alaskans to have a superior flavor when white.

SILVER SALMON (COHO SALMON): *Oncorhynchus kisutch*

Size: Averages 2 to 2½ feet.
Weight: Averages 6 to 12 pounds.
Distribution: Alaska to southern California.
Identification: Like the king salmon, but the spots are not as extensive, none being on the lower tail lobe.

GENUS SALMO

Spawns more than once. Mouths white inside. Short anal fin with 9 to 12 rays. Head comparatively small.

ATLANTIC SALMON: *Salmo salar*

Size: Averages 2 to 2½ feet.
Weight: Averages 10 pounds. Known to reach over 80 pounds.
Distribution: Northern New England to Hudson Bay. Also in Europe. Pollution and overfishing have resulted in its extermination in large southern rivers such as the Hudson and the Delaware.
Identification: Covered liberally with large, black spots which are usually X-shaped. Silvery with a brownish tinge above.

STEELHEAD RAINBOW TROUT: *Salmo gairdneri*

Size: Averages 2 to 2½ feet.
Weight: Averages 10 pounds.
Distribution: Alaska to southern California.
Identification: There are numerous dark spots on the back and unpaired fins. The color is a steely blue.

SMELTS: Family Argentinidae

These small, mostly marine, silvery fishes are among the finest if not the

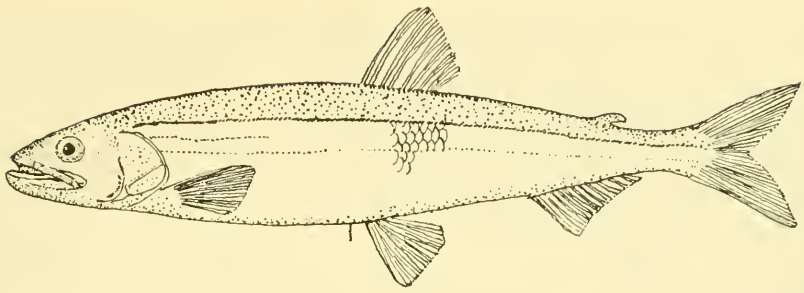


Fig. 95. American smelt.

finest of all pan fishes. They are slim of body and very similar to the salmonids, being separated from them by internal characters.

Smelts are schooling, shallow-water fishes which feed mainly on smaller fishes and crustaceans. Like salmon, they enter fresh waters to breed and may become landlocked. Most of them are characteristic of north temperate and arctic seas.

AMERICAN SMELT: *Osmerus mordax*

Size: Averages 8 inches. Up to 14 inches.

Weight: Up to 1 pound.

Distribution: The St. Lawrence River to Virginia.

Identification: There is a broad silvery stripe along the lateral line.

Habits: Smelts school in huge numbers and enter fresh water in late winter or early spring to breed, laying thousands of eggs. They prefer cool waters and move offshore in the summer. Several eastern lakes, such as Lake Champlain and some of the Great Lakes, have landlocked forms of this fish. These are active little fishes which feed mainly on small fishes and shrimplike crustaceans.

Similar Species: The surf smelt or whitebait, *Hypomesus pretiosus,* has the dorsal fin inserted anteriorly to the pelvic and is similar to the American smelt. It is found from Alaska to central California.

LIZARD FISHES: Family Synodontidae

These are shallow-water members of a largely deep-sea group, the lantern fishes, which is often placed in a separate order, Iniomi, by ichthyologists. They are rather troutlike with long round bodies, large jaws, an adipose fin, and ventral fins that are larger than the pectorals. All the lizard fishes are fiercely predatory. They sit on the bottom, resting on their ventral fins until some unsuspecting fish or crustacean swims by. Then they rush so quickly at the prey that the movement can hardly be seen. They prefer sand bottoms but may be found about reefs and rocks as well as over mud and grass.

This is one of the groups in which the normal swimming pattern has been altered. For sudden rushes, the tail fin is used, but lizard fishes do not often swim when at leisure, preferring to creep about on the bottom on their very large pelvic fins. The pectorals are held out like wings and are probably used as planing devices in their sudden rushes after prey. Lizard fishes are usually sandy-colored with dark blotches, and the head has a distinctly lizardlike appearance. They are found in the shallow, warm seas of the world.

Fig. 96. The snakefish, Trachinocephalus, *10 inches long, is usually seen motionless over sand or dead coral waiting to dart at some small fish or crustacean.*

SNAKEFISH: *Trachinocephalus myops—Figure 96*

Size: Up to almost 1 foot in length.

Distribution: West Indies north to South Carolina and south to Brazil.

Identification: The body is heavy and almost perfectly round in cross section.

Habits: This fish remains motionless even on close approach by swimmers. It is not readily frightened, and observation of it is easy, though its coloration and lack of movement make it difficult to spot.

Similar Species: The lizard fish, *Synodus foetens,* is olive-colored with yellow vermiculations, or wavy outlines, on the back and sides, and is found from Cape Cod to Brazil.

The California lizard fish, *Synodus lucioceps,* is similar to Atlantic members of this genus. It is olive-brown with a golden luster and slaty reticulations, or netlike patterns, on the back and sides. It is found from San Francisco to San Diego. Both of these fishes are much slimmer than the snakefish but have similar predatory habits.

The Eels: *Order Apodes* (*"without feet"*)

The eellike shape is repeated in several groups of fishes. Electric eels and eelpouts, both superficially like eels in appearance, are not true eels. The parallel development in these groups of the eellike shape is an adaption to a common mode of life, a life in holes and crevasses. The true eels are all rather degenerate in that there is a marked tendency toward loss of the fins and scales. The ventral fins are always missing, and the pectorals are sometimes also lacking. This forces them to swim like a snake with sinuous lateral body movements. Some have even lost the vertical fins and, hence, cannot swim but must slither about on the bottom. The operculum is also lost, and the gill opening is small, resembling a pore. In spite of all this, eels are active, voracious carnivores with dangerous teeth and unreliable tempers. Most, if not all, are chiefly nocturnal. Eels form

an isolated group, their origin and evolution being a mystery. They are found in most temperate and all tropical seas. Bertin (1942) gives a detailed account of eels.

COMMON EELS: Family Anquillidae

These most primitive eels are recognized by the presence of small scales imbedded in the skin and the large pectoral fins. They are really fresh-water fishes, which, opposite to the salmon, enter salt water to breed (a situation described as "catadromous"). Members of this family are practically world-wide, but are not found on our Pacific coast.

COMMON EEL: *Anquilla rostrata—Color Plate 1*

Size: Averages 2 feet. Exceptionally up to 5 feet. The females are larger.

Weight: Averages 1 pound. Exceptionally up to 7 pounds.

Distribution: St. Lawrence River to Brazil. A very similar species on the Atlantic coast of Europe.

Identification: The color varies from brown to black and is usually olivaceous.

Habits: The story of the common eel is one of the most remarkable known, both from the standpoint of the history of scientific speculation and that of animal adaptation. Ley (1951) tells it in excellent fashion and in some detail.

The story revolves around the eel's extraordinary reproductive habits which from earliest times were shrouded in mystery. Aristotle said that "the eel has no sex, no eggs, no semen, and originates from the the entrails of the sea." Such a statement could have been made because fishermen had never found roe or milt in eels which they captured. Up until 1777 various explanations of eel reproduction were given: they generated from slime from other eel's bodies, from bits of hair, or from sod wet with May dew. In that year a man named Mondini found what he believed were female sex organs (ovaries), but it was not until 1824 that Syrski found comparable male organs. Then in 1895 Grassi and Calondruccio kept what they believed to be an entirely different animal called "leptocephalus," a bandlike, transparent fish of up to 3 inches in length, in a tank and observed that these animals (which were actually larvae) shrank, became slimmer, and then transformed into baby eels or elvers. It was these two men that brought forth the theory that eels are in the rivers only to grow and mature and go to the sea to breed. Where and when eels breed was not known until a Dane named Johannes Schmidt, with the help of the fishermen he had supplied with deep nets, observed that the nearer to the Sargasso Sea that leptocephalus larvae were caught, the smaller they were. This was in 1904, and in 1913 Schmidt went to the Sargasso Sea and found the tiniest, most recently hatched leptocephalus of all. The mystery was solved. Eels leave the streams in the fall and travel the Gulf Stream to the Sargasso Sea to deposit their eggs, one of the most remarkable of all fish migrations.

No less remarkable is the trek the larvae make back to the streams. European larvae take three years to travel the three thousand miles, and American eels, having the shorter distance of one thousand miles to go, take only a year. The larvae grow to 3 inches in this time. When they enter fresh water, they become slim, transparent, "glass eels" and soon thereafter darken to miniatures of the adults. These young may be extremely plentiful, seeming to clog streams

with their wriggling bodies. The males probably remain in brackish waters to grow, but the females go as far upstream as they can and may even leave the water to travel overland for rather remarkable distances for a fish. The eels remain in fresh water to grow until they are about 5 to 8 years old, at which time they again go to sea. Eels only breed once, dying soon thereafter.

The mystery is not completely solved as yet. Just where in the Sargasso Sea (at what depth) the eggs are deposited is not known. They are not deposited on sargasso weed nor on the bottom, which is too deep. The smallest larvae are found at a depth of 1,000 feet, so perhaps the eggs float in deep water.

One more interesting facet should be mentioned. In 1930, the Danish ship *Dana* found a leptocephalus larva 6 feet long off South Africa at a depth of 1,000 feet. This would produce an adult eel of 60 to 70 feet. Sea serpents? No one knows.

Eels have very delicate and tasty flesh. They are largely nocturnal and eat a wide variety of animal foods. They can be pugnacious. But these eels are usually timid.

Similar Species: The conger eel, *Leptocephalus conger,* is very similar to the common eel. However, it has no scales and is put in a different family, Leptocephalidae. Congers are often confused with common eels, but are larger, reaching 8 feet and 12 pounds and have the dorsal fin prominently edged with black. They are also mainly of offshore habitats, never entering fresh water. They are found in the Atlantic from Cape Cod to Brazil.

SNAKE EELS: Family Ophichthyidae

These are very pretty and comparatively docile tropical eels. The dorsal and anal fins do not extend to the tip of the tail, and the pattern is usually a spotted one. The pectoral fins are present but small. As the name implies, these eels are extremely suggestive of snakes as they crawl about reefs and even in harbors. As they do so, they constantly poke about with their noses, on which are situated two short, stout barbels containing the nostrils. The species are numerous in all tropical seas.

SPOTTED SNAKE EEL: *Ophichthys ophis—Figure 97*

Size: Averages 2 feet. Up to 4½ feet or more.

Distribution: Florida and the West Indies to Brazil. Also to Bermuda.

Identification: Pattern as illustrated.

Habits: One of the authors had an interesting experience with one of these eels in the harbor of Nassau, British West Indies. The eel was crawling exactly like a snake over the rubbish in the harbor when it was first seen. Remembering that eels are usually not to be trusted, the author nevertheless extended a gloved hand slowly and was surprised to have the eel crawl into it. The eel did not even object to being slowly picked up off the bottom. Once again placed on the bottom, the eel found a hole, nosed about it, and retreated unhurriedly.

Snake eels probably eat a wide variety of animal food, such as invertebrates of all kinds as well as refuse and small fishes.

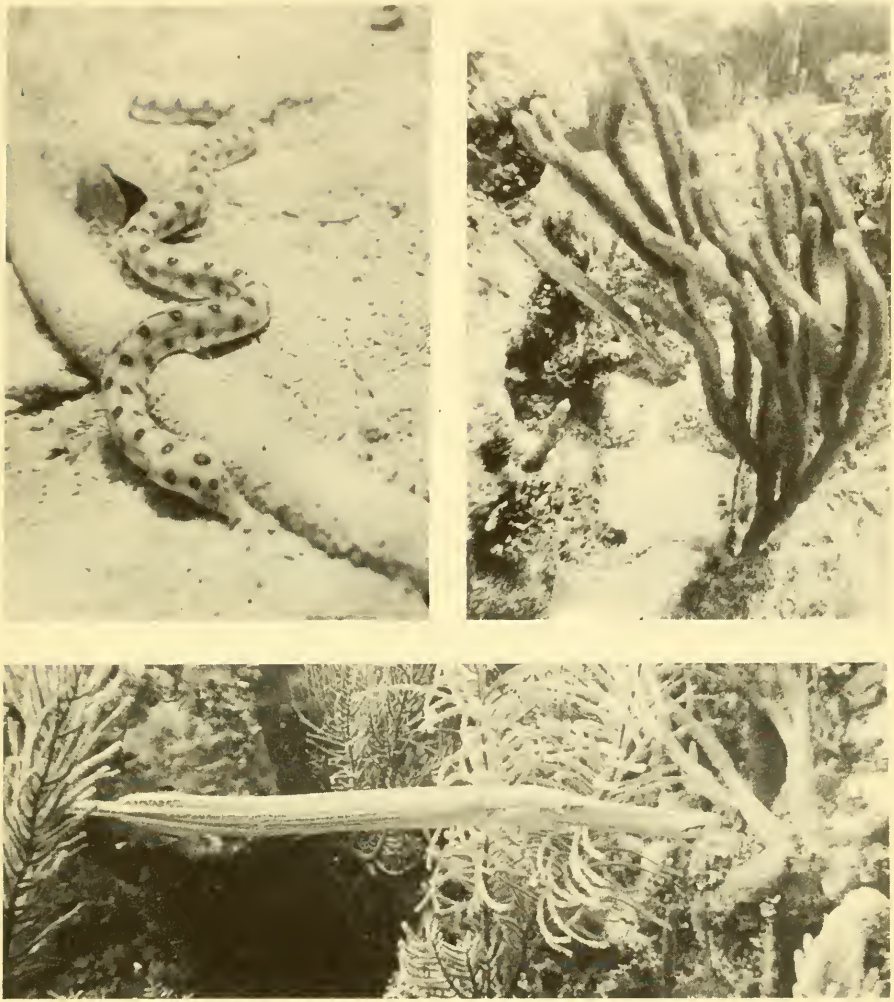


Fig. 97. Top left. This spotted snake eel, Ophichthys, *is beautifully colored with pale yellow ground color and brown spots. Top right. The trumpetfish,* Aulostoma, *will frequently imitate gorgonian sea whips when alarmed. Bottom. This is the trumpetfish as it normally appears, gliding slowly through sea feather gorgonians.*

MORAYS: Family Muraedinae

These reef fishes of tropical seas have no pectoral fins. The skin is wrinkled near the small, circular gill openings so that the neck seems like a pouch. They have the habit of sitting entwined in reefs, gaping menacingly. The pugnacious disposition and large, sharp teeth are well known. In spite of the fact that they are not known to bite if left unmolested, it would be very unwise to attempt to provoke one. Several persons have been very badly injured and

even killed when unwisely spearing or otherwise tormenting morays. They are especially dangerous if brought into a boat. Rather small morays have been known to strike viciously at men in boats, driving them into the water and leaving the eel in sole possession. Contrary to popular belief, American morays do not have poisonous bites, but the bites are very likely to become infected.

Morays ambush small fishes and crustaceans from their holes in the reef. They do not like to swim in open water, probably because of larger predators. They are chiefly nocturnal and are much more common on reefs than a first glance would reveal. All one has to do is drop a bit of fish or lobster head near a likely hole and a moray will often appear. Morays can be trained in captivity. One zookeeper had a moray that allowed him to handle it.

Morays, which are edible, are found on reefs the world over. The species range from 2 inches to over 10 feet in length.

SPOTTED MORAY: *Gymnothorax moringa—Color Plate 1*

Size: Up to 3 feet.

Distribution: Florida and the West Indies to Brazil.

Identification: The color varies from almost white to a yellow or greenish-brown ground color. There are prominent dark spots and reticulations. The color may vary to match the environment.

Habits: This is the most common West Indian moray. It is common in holes and interstices in coral heads or even in harbors about pilings.

Similar Species: The Californian moray, *Gymnothorax mordax,* has a similar pattern and color. It reaches 5 feet and is found from Point Conception to Cedros Island.

GREEN MORAY: *Gymnothorax funebris—Color Plate 1*

Size: Averages 3 feet. Commonly to 6 feet and may very rarely reach 10 feet.

Weight: Rarely 30 pounds.

Distribution: Both coasts of tropical America. Common from Florida to the West Indies.

Identification: The color is usually a brilliant to brownish green. The coloration is unique, caused by the combination of a blue skin and a yellow mucus. Dark gray or brown individuals may lack the yellow coloring in the mucus.

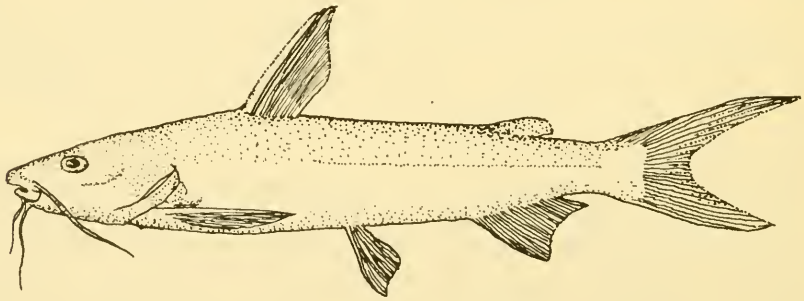


Fig. 98. Sea catfish.

Habits: The habits are the same as those of the spotted moray although the green moray gets into somewhat deeper waters. It is a very powerful predator.

Catfishes: *Order Ostariophysi* (*"inflated bone"*)

The catfishes are only a part of this large, mainly fresh-water order, but they are the only marine members. The great majority of fresh-water fishes are ostariophysians. Minnows, suckers, chubs, carp, and others make up one group called "cyprinids" and many tropical aquarium fishes, including South America's dreaded piranha, make up another large group called "characins." The electric eel and its relatives compose still another group. The catfishes themselves, though not the largest group in the order, have almost a thousand species. Out of all this great array, only two species of catfishes habitually get into sea water in North America, and these do not stray far from land.

Ostariophysians are closely related to the herringlike fishes but possess one very important difference which, though internal, is important in understanding these fishes. It is the Weberian apparatus, a series of large, inflated vertebrae near the head which are connected to the air bladder and the inner ear and therefore act as a completely unique organ of hearing. The use to which this more sensitive hearing apparatus is put is not known.

The catfishes may immediately be recognized by the long barbels about the mouth. These are used as tactile and taste organs to detect food, and as feelers in general. The dorsal and pectoral fins are each armed with a single stout spine, which is able to inflict a painful wound. Luckily, the spines of the North American marine catfishes are not poisonous as are those of the mad tom and stone cats, *Noturus* and *Schilbeodes,* both inhabitants of fresh water. The spines are used defensively only.

Catfishes have the ventral fins far back on the belly and possess an adipose fin. These bottom fishes eat a wide variety of food, being practically omnivorous in habits.

SEA CATFISHES: Family Siluridae

These fishes are distributed over the world's warm seas with the exception of the North Pacific and European waters.

SEA CATFISH: *Galeichthys felis*

Size: Up to 1 foot.

Distribution: Cape Cod to the Gulf of Mexico. Not common north of Virginia.

Identification: Silvery green above and white below. There are two barbels on the upper jaw and four on the lower.

Habits: This is an abundant shore fish in harbors and over all kinds of bottoms, but prefers rocky shores. It feeds mainly at night on just about anything it can swallow. Sea cats travel in schools of up to 200 fish.

GAFF-TOPSAIL CATFISH: *Bagre marinus*

Size: Averages 15 inches. Up to 2 feet.

Weight: Averages 1½ pounds. Up to 3 pounds.

Distribution: Cape Cod to Panama. Not common north of Delaware.

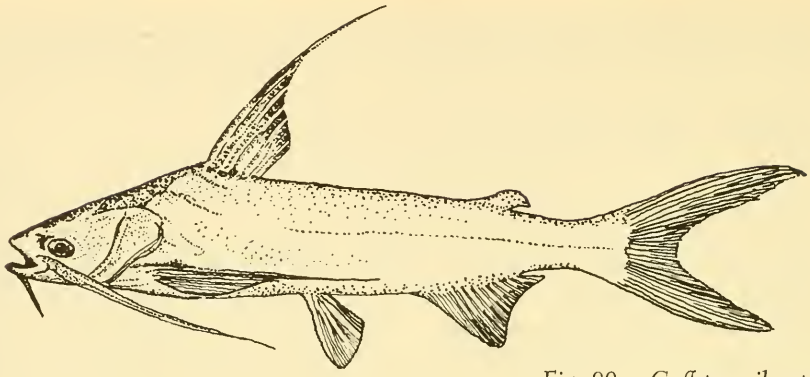


Fig. 99. Gaff-topsail catfish.

Identification: The two upper jaw barbels are very long, and the lower jaw barbels are only two in number. The fish is named from the shape of the dorsal fin.

Habits: The habits of this catfish are similar to those of the former species, but there is a tendency to be more active. The breeding habits are interesting. Very large eggs, up to an inch in diameter, and only about four or five dozen at most in number are laid in June and July. The male carries these eggs in his mouth until they are hatched. After the young hatch out, they are still carried in the male's mouth until the yolk sac is absorbed, at which time they are 3 inches long. During this whole time, a period of two weeks, the male takes no food.

The "Middle Fishes": *Order Mesichthys*

Several quite different suborders are here grouped together because they represent a transition from the herringlike fishes to the advanced spiny-rayed fishes. There is a tendency in these suborders for the ventral fin to be moved forward, the pectorals to be placed high on the body, and the dorsal fin to acquire spines. But, as we shall see, these groups are so different that this order is probably less biologically real, in terms of evolution, than merely convenient.

Pikes: *Suborder Haplomi*

Here we meet another predominantly fresh-water group with many famous members ranging all the way from the powerful pikes and muskellunges to the modest guppies, mollies, swordtails, and platies. There is only one family that reaches salt water, that of the killies.

KILLIES: Family Cyprinodontidae or Poecilidae

The round body is compressed behind but depressed at the head so that the mouth is very wide. The ventrals are placed back on the belly and are nearly equal to the pectorals in size. The best field mark is the placement of the dorsal fin far back directly over the rather large anal fin. The many species are usually olivaceous in color and swarm in shallow, salt, brackish, or even

fresh water, being favorite pets of small boys at the shore in summer. Killies are among the hardiest of fishes, able to survive an amazing variety of salinities, temperatures, and pollutions. They are found on both coasts of North and South America and in Asia and Africa.

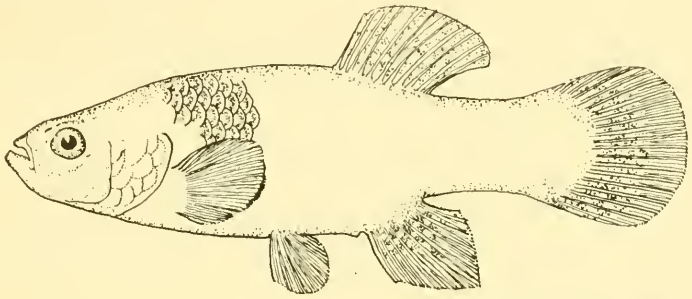


Fig. 100. Common killifish.

COMMON KILLIFISH: *Fundulus heteroclitus*

Size: Averages 2 inches. Up to 6 inches.

Distribution: Gulf of the St. Lawrence to the Gulf of Mexico.

Identification: The males have pearly spots, and the females are a solid olive-green.

Habits: Killies are active, swarming little shore fish which eat almost anything, including large numbers of mosquito larvae. They like weedy places along the tide zone and are frequently trapped in high-sided tidepools. They are not usually trapped in low-sided tidepools since they are able to climb out of these and travel overland for ten feet or so to open shallow waters. Killies lay eggs in weeds in spring. The male takes on orange hues at that time.

Synentognaths: *Suborder Synentognathi*

This group includes the gars, halfbeaks, and flying fishes. All of these fishes are primarily silvery with bluish or greenish backs, and all are characteristic of surface waters of warm temperate and tropical seas. The ventral fins are far back on the belly, and the lateral line is unique in that it follows the belly outline. There is a marked tendency for these rapidly moving, active fishes to take to the air, so most have an enlarged lower lobe of the tail fin, and some also have enlarged pectoral and ventral fins, a trend culminating in the flying fishes.

A good rule of thumb for recognizing members of the group is that all either possess winglike pectoral fins or elongate, beaklike jaws, and all have the dorsal and anal fins far back on the body. The diets of synentognaths vary. Their eggs have threadlike tufts on them which serve to anchor them to seaweed and to each other. Most of them are schooling. They are cosmopolitan in warm seas.

GARS, BILLFISHES, AND NEEDLEFISHES: Family Belonidae

These are the largest of the synentognaths and the most voracious. The elongate jaws and needlelike teeth are admirably suited for catching small fish.

The flesh is green but is very good to eat. Gars are extremely swift and, when disturbed, are known to leap like spears through the air. People have been known to be seriously injured when struck by a leaping fish. They are often seen skittering very rapidly for some distance over the water's surface with only their tails in contact with the water. They are common near shore in all tropical seas and are often seen in harbors. The authors have seen them under water but found them difficult to photograph because of their constant activity and speed. Gars travel in small schools usually. The species are many and hard to separate.

HOUNDFISH: *Strongylura raphidoma—Color Plate 1*

Size: Averages 2 feet. Up to 5 feet. Largest of the family.

Distribution: Florida and the Caribbean. Straggles to New Jersey.

Identification: The beak is rather short and strong, and this fish is large compared with others in the family.

Habits: This species in particular has the habit of leaping from the water and can be dangerous to people in small boats who get in their way. The houndfish is a voracious feeder on small, surface fishes.

HALFBEAKS OR SCISSORS: Family Hemirhamphidae

These fishes are very similar to the gars but are slightly less elongate and have only the lower jaw lengthened. (Only one species, the hardhead, *Chriodorus antherinoides,* has both jaws short.) Halfbeaks are swift, surface fishes and tend toward "flying" even more than do the gars. One, the flying halfbeak, *Euleptorhamphus velox,* has expanded, winglike pectoral fins. Like the gars, they are characteristic of all warm seas, mainly near shore, but unlike the gars, most are small and all are herbivorous. Most also have a wide silvery lateral stripe. The toothless jaws are used to scoop algae into the mouth though the details of how this is done are poorly known. Hesse, Allee, and Schmidt (1951) say that they eat some algae from the bottom, but this seems odd for this surface fish. The schooling tendency is more marked than in the gars.

HALFBEAK: *Hyporhamphus unifasciatus—Color Plate 1*

Size: Up to 1 foot.

Distribution: Florida and the West Indies. Reaches Massachusetts in the Gulf Stream.

Identification: Same as for the family.

Habits: Schools of this common surface fish are common in quiet, shallow waters throughout its range.

Similar Species: The West Coast halfbeak, *Hyporhamphus rosae,* reaches only 6 inches and is common in sheltered bays from southern California southward.

The Atlantic saury or skipjack, *Scomberesox saurus,* belongs to a different family, Scomberesocidae, but is very similar to the halfbeaks. The jaws are toothless and thin, and the upper is nearly as long as the lower. The dorsal and anal fins are followed by finlets as in the mackerel. Great schools of these herbivorous fish are mainly found in temperate seas offshore.

The Pacific saury, *Colobis saira,* is like the Atlantic species and is found

from Baja California to Japan. Both reach 1½ feet, though the Atlantic form has been recorded to 30 inches. Schools of thousands of individuals will rise at once out of the water, leaping, and skittering on the surface, when pursued by predators such as tuna and bluefish.

FLYING FISHES: Family Exocoetidae

The "little bluebirds" of the sea do not have extended beaks like other synentognaths, but they can be immediately recognized by the very large wing-like pectorals. In these fish, the leaping tendencies of all synentognaths reach a climax. Almost anyone who has traveled tropical seas in a boat has seen them repeatedly spring up in front of the boat either singly or several at a time. They may sail off singly in any direction regardless of the direction of the wind or several may sail in precise formations. Flying fishes are swift, pelagic fishes usually found over deep water.

Breder and Edgerton (1946) have examined the flight of these fishes by using a high-speed camera and stroboscopic lights. They found that before take-off the tail beats as many as fifty times a second in order to drive the fish to the 40 mph necessary for take-off. The pectorals (and sometimes also the expanded ventrals) are kept folded against the sides until the fish's foreparts leave the water. Then they are spread. The long lower tail lobe leaves the water last and gives the extra taxiing push (of ½ to 1 second duration) necessary to add speed for a sustained glide. As the speed drops to 25 mph, the fish either re-enters the water or dips its tail in for another push and another glide. Single glides average 2 to 6 seconds and 40 to 50 yards but have been observed lasting up to 10 seconds. The fish can bank by manipulating the pectorals. Several single glides may be made together so that one flight may cover a quarter of a mile or more. The pectorals may seem to vibrate but are not flapped. Only one fish, the fresh-water hatchet fish, *Gastropelecus,* is known to flap its pectorals in flight.

Flying fishes eat all sorts of small surface-living invertebrates. Atlantic species build nests for their eggs by binding floating Sargasso weed together. They "fly" in order to escape their many enemies, particularly the dolphin, *Coryphaena,* and the bonito, *Katsuwonus.* They are found in all tropical seas.

SHORT-WINGED FLYING FISH: *Parexocoetus mesogaster—Color Plate 1*

Size: Up to 7 to 8 inches.

Distribution: Cosmopolitan in warm seas. Straggles to Cape Cod in the Gulf Stream.

Identification: The "wings" are somewhat shorter than those of other species.

Similar Species: The largest of all flying fishes and the one with the best developed powers of flight is the Californian flying fish, *Cypselurus californicus.* It reaches 18 inches in length and is found solely off southern California.

Hemibranchs: *Suborder Hemibranchi*

This group includes the sticklebacks and trumpet fishes. There are several spines preceding the dorsal fin and the ventrals are abdominal. The families are widespread over the world and are varied in habits.

STICKLEBACKS: Family Gasterosteidae

These are small fishes typical of bays, estuaries, brackish waters, and streams of north temperate and arctic seas. The ventral fins are each supported by a stout spine, and there are 2 to 9 spines preceding the soft dorsal fin. They are mainly olivaceous in color, but in the spring when they enter fresh water to breed, the males become flushed with a striking and quite beautiful red on the sides and head. At that time, the eggs are laid in nests built around the stems of water plants, and the pugnacious male guards the nest.

TWO-SPINED STICKLEBACK: *Gasterosteus aculeatus*

Size: Up to 4 inches. Females are larger than males.

Distribution: Circumpolar. South to New Jersey and to Baja California.

Identification: Separated from most other sticklebacks by the presence of only two dorsal spines.

Habits: The food is varied from small fishes and crustaceans to algae.

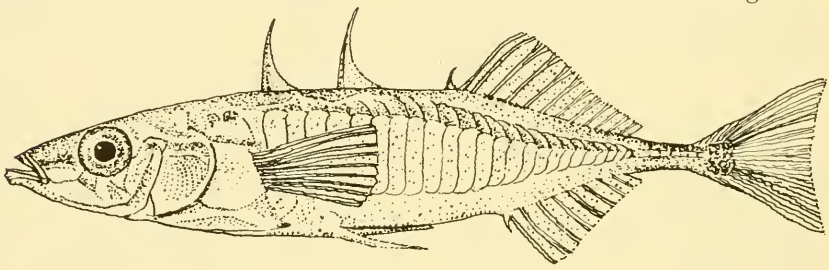


Fig. 101. Two-spined stickleback.

TRUMPET FISHES: Family Aulostomidae

These are extremely odd, elongate, and compressed fishes, characteristic of coral reefs all over the world. The colors are mostly browns and dull yellow. It is the movement of this fish that is most fascinating. They seem to float through the water with no body motion whatsoever. Actually, the nearly transparent dorsal and anal fins are the active propulsion units, waving rapidly to and fro. If the fish has to move quickly, it does so by a strong lateral motion of the tail as do other fishes, but the trumpet fish would rather not so exert itself. It far prefers to move on its slow course, head up or head down, backwards or forwards surveying all with its large eyes. It seems to depend on concealing coloration and habits for protection. It has been observed by the authors to stand with its head down in imitation of the branches of a gorgonian when approached, and it will frequently keep to the opposite side of objects in the water like a squirrel does on a tree trunk. Trumpet fishes are solitary and very common. They eat small fishes, crustaceans, and worms. The small mouth is at the end of a very long snout.

TRUMPET FISH: *Aulostoma maculatus*—*Figure 97*

Size: Up to 3 feet long and possibly longer. Averages 1½ to 2 feet.

Distribution: Coral reefs of Bermuda, Florida, and the West Indies.

Identification: The principal ground color is brown, but occasionally very yellowish ones are seen.

Similar Species: The cornet fish, *Fistularia tabacaria,* is of a different but very similar family, Fistulariidae. It is typically West Indian, and reaches larger size (to 6 feet) and has a proportionately longer snout than the trumpet fish. There is a long filament proceeding backward from the middle of the caudal fin.

Lophobranchs: *Suborder Lophobranchi*

This group includes the sea horses and pipefishes. The scales in these very specialized fishes form a stiff but movable encasing armor. The mouth is small and at the end of a long snout.

All lophobranchs are carnivorous, feeding on very small animals, mostly crustaceans. Most have reduced tail fins (sea horses have none) and depend on the fluttering dorsal and pectoral fins for movement. In addition, the tails of many (especially sea horses) are prehensile. Movement is stiff but graceful. The breeding habits are very odd. The female deposits the eggs, up to a few hundred, in a pouch on the male's belly. There they incubate and hatch. Miniature young emerge to relieve the male of his burden. The male frequently rubs his pouch against some object to hasten the multiple birth. Lophobranchs are probably degenerate offshoots of the hemibranchs. They are typical of the sandy, shallow, eelgrass-covered waters of temperate and tropical seas.

SEA HORSES AND PIPEFISHES: Family Syngnathidae

The sea horses and pipefishes differ only in that the latter are straight while the former have a head that is bent sharply down and travel upright, looking like a chess knight. Both of them depend on concealing coloration and habits for protection. Some (notably the East Indian *Phyllopteryx*) even have fantastic filamentous extensions on their bodies so that they resemble seaweed.

NORTHERN PIPEFISH: *Syngnathus fuscus—Color Plate 1*

Size: Averages 6 inches. Up to 1 foot.

Distribution: Halifax to North Carolina. Most common near New York.

Identification: The color varies from green to brown, depending on the environment.

Habits: Moves stiffly in shallow water over weedy beaches. It is fond of the little shrimp *Gammarus.* Most movement is by means of the dorsal fin as in the sea horse. The tail is used for movement only when the fish gets excited. The courtship is very strange. The two mates swim erect, their bodies in S-shaped curves. As they pass each other, they touch and become more and more aroused until they twine their S-curved bodies together—looking very much like the U.S. Army Medical Corps insignia—and the female deposits some eggs in the pouch of the male. This process is repeated several times until all the eggs are laid.

Similar Species: A large 18-inch species, the great pipefish, *Syngnathus californiensis,* occurs on the California coast and northward.

NORTHERN SEA HORSE: *Hippocampus hudsonius—Color Plate 1*

Size: Averages 4 to 5 inches. Up to over 6 inches.

Distribution: Carolinas to Cape Cod. Rarely to Nova Scotia.

Identification: The size is rather large (for a sea horse), and the color is brownish over all.

Habits: This is a slow-moving fish, most often seen anchored to eelgrass or other objects with the prehensile tail. The dorsal fin is the principal organ of propulsion. The earlike pectorals also help, but these fishes are not very mobile. Because of this, the swim bladder is large and well developed, and if a little gas is removed from it, the fish will sink to the bottom (Gudger, 1905).

By means of stroboscopic lights and a high-speed camera, Breder and Edgerton (1942) found that the dorsal fin movement is very complex and fast. The fin moves from side to side thirty-five times a second, nearly as fast as a hummingbird's wing. There are also wavelike motions in this fin passing from the top to the bottom, ten waves passing through this fin in a second. This locomotor method, as well as the habit of living in seaweed, limits sea horses to a small size. It is probably not coincidence that the largest sea horse lives where there are the largest seaweeds. Movements of the head and, thus, the pectoral fins, change the direction of travel.

Similar Species: The giant sea horse, *Hippocampus ignens,* of Magdalena Bay in Baja California and southward, grows to 1 foot long and is the largest sea horse.

Spiny-Rayed Fishes: *Order Acanthopterygi* (*"spiny fins"*)

The great majority and the most varied of fishes belong in this group. The great array of species presents difficult problems in identification because of the similarities in appearance between species as well as the variations of color and pattern within many of them. Nevertheless, this cannot help but be a fascinating group, as well as a challenging one, because the most colorful of all fishes, as well as those with the most complex and interesting social behavior, are found here.

All spiny-rayed fishes have at least one, and usually all, of the following characteristics: (1) spines on the forward ends of the pectoral and ventral fins, (2) the pectorals placed high on the body above the abdomen, (3) the possession of two dorsal fins, one spiny and one soft, and (4) ventral pins placed under the pectorals.

There are several large suborders. These are the dominant fishes of today.

Mulletlike Fishes: *Suborder Percesoces*

These are the only spiny-rayed fishes that still have the ventral fins placed on the abdomen in back of the pectoral fins. Their bodies are rather elongate. There is a small, spiny dorsal fin widely separated from the soft dorsal. The three families of this suborder constitute the most primitive of all spiny-rayed fishes. They are typical of the warm temperate and tropical seas of the world.

SILVERSIDES: Family Antherinidae

These small fishes, also known as "smelts," "whitebait," and "fry," school by the thousands and look much like anchovies or small smelts, but these latter do not have two dorsal fins. Silversides have a brilliant silver stripe on the

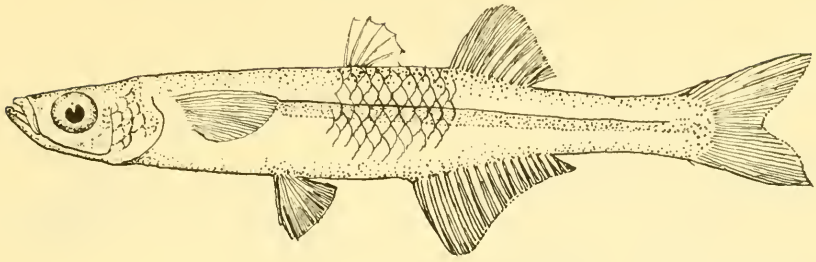


Fig. 102. Tidewater silverside.

side and none of them has a lateral line. All live near shore and may enter brackish water and fresh water. They furnish excellent food and for that reason are also called *pescados del rey* or "fishes of the king." They are cosmopolitan in warm seas.

TIDEWATER SILVERSIDE (WHITEBAIT): *Menidia beryllina*

Size: Up to 3 inches.

Distribution: Massachusetts to the Gulf of Mexico.

Identification: Same as for the family.

Habits: This is a typical schooling silverside which is carnivorous, feeding on all kinds of small animal life. It is common in shallow water and enters brackish and fresh water. Spawning occurs in the summer. The eggs have adhesive threads by which they are anchored to the bottom and attached to each other.

Similar Species: One of the West Coast species, the grunion, *Leuresthes tenuis*, deserves mention because of its extraordinary breeding habits. It is a small, 6-to-8-inch fish common from San Francisco to Baja California. From March to August, grunion come in to sandy shores to breed. The timing is precise. They ride the crest of a wave to the beaches about fifteen minutes after high tide on the first four nights after the highest tide of the full moon. Between the time the wave has receded and the onrush of the next wave, the female digs tail first into the sand and, with the male curled about her head, deposits her two thousand eggs. Spawning continues for about an hour, different fish coming in and going out with each wave. The eggs remain in the sand until the next high tide wets them exactly two weeks later. Then the eggs hatch, and the young escape into the sea. So striking is this procedure that local chambers of commerce formerly advertised it as a tourist attraction, and it became necessary to protect grunions from April to June by law.

MULLETS: Family Mugilidae

Mullets are schooling fishes which are similar to silversides but which have small mouths, no silvery lateral stripe, and are comparatively robust. They are mud-eaters, that is, they take mud in the mouth, strain animal and plant substance from it with a sievelike arrangement in the throat, then spit the remaining material out. They are raised in oriental fishponds for food on a commercial basis. The ama-ama is one particularly well-known mullet of Hawaii much fabled in song and story by the Polynesians. Mullets are cosmopolitan in warm seas. They are an excellent food fish.

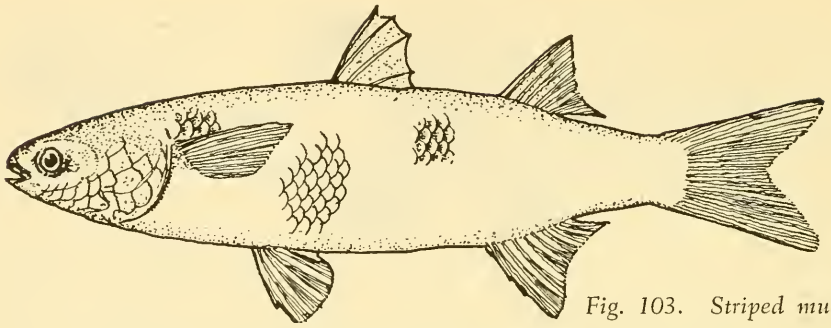


Fig. 103. Striped mullet.

STRIPED MULLET (FATBACK, JUMPER): *Mugil cephalus*

Size: Averages 1 foot. Up to 2 feet.

Weight: Averages 1 pound. Up to 4 pounds.

Distribution: Cosmopolitan in warm seas. North to Maine and Monterey, south to Brazil and Chile. Also in the Salton Sea.

Identification: The sides are brassy or silvery with faint, dark, horizontal stripes.

Habits: Mullets prefer still, shallow water with grassy, sandy, or muddy bottoms. They frequently enter brackish or salt waters. These are somewhat dull fishes which grub around, head down, in mud like a bunch of chickens.

BARRACUDAS: Family Sphyraenidae

These fishes are impossible to mistake for any others. The large mouth is armed with very heavy, compressed teeth. There is a slim, pikelike body with a huge tail. The eye is large, silvery, and appraises the swimmer with an inquisitive, menacing look. The ground color is silvery. There are sometimes blotches on the sides and back. The fins are dark. Barracudas are very much like pike in habits. They depend on extremely fast rushes at living fish prey for food, using the teeth in a slashing manner. All are powerful and voracious, but most of the several species are rather small, not reaching over 18 inches (the sennets and the guaguanche). Their distribution is world-wide in the tropics.

GREAT BARRACUDA (PICUDA): *Sphyraena barracuda—Figure 104*

Size: Averages 2½ feet. Reaches 6 to 8 feet. Doubtfully reported up to 10 feet.

Weight: Averages 5 pounds. Large at 50 pounds. Reaches 100 pounds.

Distribution: Florida to the West Indies.

Identification: This is the largest barracuda and is compressed compared to other species.

Habits: This very swift, predatory, shallow-water fish is undoubtedly dangerous under certain circumstances. It travels singly or in schools. A swimmer in tropical waters can count on having one or more about him much of the time, not because the fish is aggressive, but because it is curious. Barracudas will approach the swimmer rather closely, but do not themselves like to be approached. Frequently, if approached, they will gape, show their teeth, and retreat out of sight, usually to return in a few minutes. The fish will advance

and retreat a few times, then leave. The best tactic to use to entice one to come close for photographic purposes is to nonchalantly turn your back and pretend not to notice. The barracuda will approach quite closely. Barracudas have been known to follow persons walking along the shore, another illustration of their curiosity.

There are times, however, when the barracuda is not just nosy. There are definite records of attack. The bite can always be recognized because it is clean and straight, not like a shark's round and jagged wound. Barracudas usually strike only once, leaving as rapidly as they came. Springer (1943) has analyzed the factors influencing barracuda attack and finds that the danger increases with (1) water over 66° Fahrenheit, (2) increased water turbidity, which impedes the barracuda's vision, (3) the presence of bright colors, shiny or fluttering objects, and (4) fast, sudden, irregular movements across the field of vision.

Barracudas are diurnal and depend upon their eyesight to hunt. If the swimmer acts like a fish, avoids carrying wounded fish or spearing fish in the barracuda's presence, and does not splash on the surface, there is very little likelihood of attack.

The flesh of barracudas is good eating. Although it has been reputed in some places to cause "ichthyocism," a form of food poisoning, this seems doubtful according to present knowledge.

Similar Species: The Pacific barracuda, *Sphyraena argentea*, grows to 5 feet and is found from San Francisco to the south. It is slimmer than the great barracuda.

Threadfins: *Suborder Rhegnopteri*

The one family of threadfins is very much like the mullets, but the unique pectoral fins are split into two parts, the lower one of which is composed of seven or eight threadlike rays. The mouth is under a pronounced snout. They are common in all warm seas except those of Europe.

Fig. 104. The great barracuda, Sphyraena, *is often seen followed by several skipjack,* Caranx ruber, *which might share in the crumbs of the table. This barracuda was four feet long.*

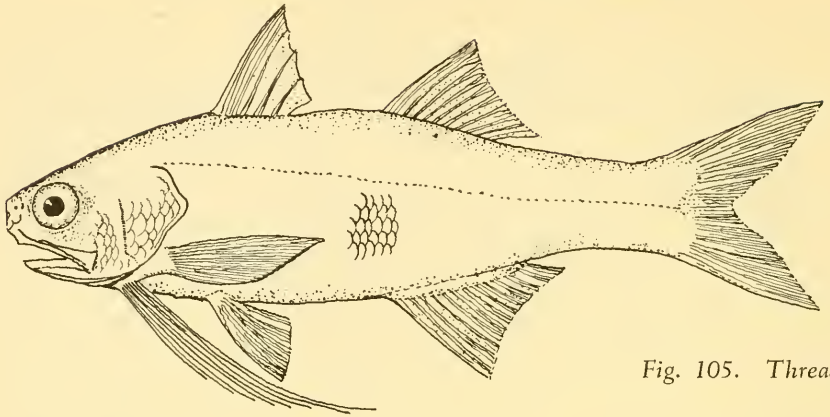


Fig. 105. Threadfin.

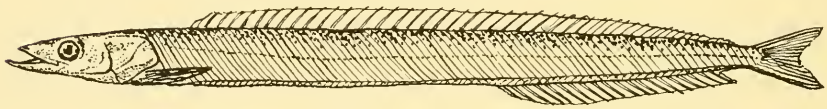


Fig. 106. Sand launce.

THREADFINS: Family Polynemidae

THREADFIN: *Polynemus octonemus*

Size: Up to 1 foot.

Distribution: West Indies and the Florida Keys. To the Gulf of Mexico, straggling to Cape Cod.

Identification: The color is yellowish white, olivaceous above.

Habits: This is a fish of shallow, sandy shores. It travels solitarily or in small groups and is carnivorous, feeding on all sorts of small animals. The threadlike fins are probably tactile in function.

Sand Launces: *Suborder Ammodytoidei*

There is one family of these very odd fishes. They dive like lances into the surf sand of shallow shores, and this habit has given them their name. The shape itself should be enough to identify them. The skin has many curious cross folds, and the scales are very reduced. These are fishes of the North Atlantic and North Pacific.

SAND LAUNCES: Family Ammodytidae

SAND LAUNCE: *Ammodytes americanus*

Size: Up to 6 inches.

Distribution: Newfoundland to Cape Hatteras.

Identification: Same as for the family.

Habits: These fishes travel in huge schools near the shore, particularly in the north. They dive in and out of sand with great facility and often remain there

while the tide is out. Their reason for doing this is not known. As pan fish, they are excellent.

Berycoids: *Suborder Berycoidei*

Several archaic characters seem to indicate that these fishes bear an ancestral relationship to the rest of the spiny-rayed fishes, probably forming a link between these and the herringlike fishes. The bodies are largely compressed and the fins and bodies very spiny. There are two distinct families in our waters.

SQUIRREL FISHES: Family Holocentridae

These are among the most numerous and beautiful of reef fishes. Their bodies are red, and the fins are tinged with yellow. The exceptionally large eye indicates nocturnal habits. Nearly every coral head forms the home of several squirrel fishes. By day, they stay holed up, but they will come out to curiously view a swimmer. By night, beginning at dusk, they become active and feed out in the open. The large eye and large spiny fins identify them. Squirrel fishes also have a large pre-opercular spine which can inflict painful wounds on persons handling them. They are common in all coral seas.

SQUIRREL FISH (SOLDIER FISH): *Holocentrus ascensionis*—*Color Plate 3*

Size: Averages 8 inches to 1 foot commonly. Rarely to 2 feet.
Distribution: Florida and the West Indies.
Identification: Same as for the family.
Habits: This is a timid fish by day, but it actively and pugnaciously feeds on fishes and crustaceans at night. It is among the most common of reef fish and, as is the case with many of them, seems to "home," or return to the same hole on the reef, probably not straying far from it even by night. It is solitary as would be expected from the foregoing.

SURMULLETS: Family Mullidae

These are very easy fishes to recognize, both because of the long chin barbels that all of the species possess and the wide separation of the spiny and soft dorsal fins. The feeding method is also distinctive. The two chin barbels are held like long, active feelers in front of the fish, exploring the bottom over which the fish is feeding. When so engaged, the fish presents a very amusing appearance as it grazes and pokes busily about like a chicken. The diver usually can approach them closely. Some school and some swim solitarily or in the company of other reef fishes. They are carnivorous, feeding on small invertebrates. Many books about fish report that most surmullets are bright red, but the diver will discover that this is true of many of them only when the fish is dead, dying, or excited. When naturally swimming about, most species have a pale whitish to pink or rosy ground color.

Surmullets are found in all tropical and subtropical seas and are extremely characteristic of reef areas.

SPOTTED GOATFISH: *Upeneus maculatus*—*Color Plate 3*

Size: Up to about 10 inches.
Distribution: West Indies north to Florida.

Identification: The ground color varies somewhat with the environment, but the three or four large dark blotches on each side are the best identifying mark. The most common ground color is white to rose. Red specimens are sometimes seen.

Habits: This fish is usually found swimming singly or with other reef fish such as small parrot fishes. It feeds in sand near coral heads.

Similar Species: The northern goatfish, *Mullus auratus*, is another West Indian sandy bottom fish, but it strays north to Cape Cod. It is red above with light yellow sides and with two rows of light blue spots on the sides above the lateral line.

The yellow goatfish (*color photograph*), *Upeneus martinicus,* differs from most of the goatfishes in that it schools densely and acts much like the smaller schooling grunts in habits. There is a bright yellow stripe extending horizontally from the eye, down the middle of the pale, whitish body, and onto the tail. This coloration thus strongly resembles that of the yellowtail snapper (*Ocyurus*).

The only common West Coast goatfish is *Upeneus dentatus*. It occurs from Cape San Lucas southward. It is rosy with a red stripe running down the side and onto the tail fin.

Mackerellike Fishes: *Suborder Scombroidei*

These primarily oceanic fishes are mainly offshore predators and are so diverse, numerous, and confusing that we will be able to treat them only in a summary way. They are mostly rather large, schooling fishes of the open seas and as such are difficult for the swimmer to observe. Nevertheless, the opportunity to study them under water should be grasped because little is known about most of them. In general, they have smooth, streamlined bodies that offer little resistance to the water. They have pointed heads, constricted caudal peduncles, and large lunate tails. These are all adaptions for swift movement. It is in this group that we find the swiftest of fishes as well as the swiftest things that swim. Some of them even have slots into which the dorsal and pectoral fins fold in order to further reduce water resistance. The typical families of the group have separate spiny and soft dorsal fins, and the soft dorsal and the anal fins are of similar size and shape, being directly over and under each other. Most of them are highly predacious, and many are schooling. The color is usually silvery with a greenish or bluish back. As we shall see, there are a number of families which seem to fit none of these rules. The most constant features are the silvery, iridescent ground color and the similar soft dorsal and anal fins, but even these rules are frequently broken.

TRUE MACKERELS: Family Scombridae

The swimmer will not often encounter the largest of the species of this family, but if he does he is in for an almost unmatchable thrill because of the speed, size, and silvery beauty of these fishes. There are about sixty very similar species in the world of these mostly predacious fishes. Many of them are cosmopolitan, of great size, and commercially valuable. All are schooling and of wide distribution.

As a group, identification is rather easy, there being a series of small finlets behind the soft dorsal and anal fins. The shape does not vary much from a torpedolike spindle, the caudal peduncle being very slim and supported by strong lateral keels. The colors are primarily silvery with blue or green and some yellow markings.

These and the spearfishes are the swiftest of the swift. A speed of 40 to 50 mph is probably attained by the larger species. The body is very smooth, even the eyes and gill cover being practically flush with the extremely powerful body. Among the fishes, these are the wolves of the sea, running down prey. A few, however, are plankton eaters. Most are primarily pelagic and wandering, coming inshore when the seas are calm and warm. In most, the pattern and causes of migration and the breeding habits are not well known.

COMMON ATLANTIC MACKEREL: *Scomber scombrus*–*Color Plate* 2

Size: Averages a little over 1 foot. Up to 2 feet.

Weight: Averages a little over a pound. Up to 7 pounds.

Distribution: In the North Atlantic from Labrador to Cape Hatteras and from Norway to Spain.

Identification: Its small size and the wavy blue markings on the back serve to identify it.

Habits: Contrary to most of the family, this is a plankton feeder primarily, though many small fishes are also eaten. The long gill rakers serve to strain small animals from the water. The schools are especially large, and they move in response to temperature. The northerly migration begins at Cape Hatteras in March and ends at the St. Lawrence by June. This migration is a coastal one. In the fall, the southerly migration is offshore and in deeper waters. Mackerels produce huge numbers of floating eggs, up to 500,000 per female, in the summer. The mackerel's enemies are many. In the north the gannets, among the birds, take a heavy toll. Many fishes and squid prey upon the young.

Similar Species: The Atlantic chub mackerel, *Pneumatophorus colias*, is very similar in appearance to the common mackerel, but the wavy lines on the back are about twice as fine and numerous, and the size is smaller, rarely being over 1 foot or 14 inches. It is found from the St. Lawrence south to Virginia.

The Pacific mackerel, *Pneumatophorus japonicus*, is very similar to the chub. It is found from Alaska to Baja California and is abundant from Monterey Bay southward. It reaches 20 inches.

The frigate mackerel, *Auxis thazard*, is a species found in all warm seas, reaching northward to Cape Cod and probably to southern California. There are only a very few fine wavy marks on its back. It reaches 14 inches in length.

SPANISH MACKEREL: *Scomberomorus maculatus*–*Color Plate* 2

Size: Averages 18 inches. Up to 4 feet.

Weight: Averages 2 pounds. Up to 20 pounds.

Distribution: Tropical waters from Cape Hatteras to Brazil. Straggles to Maine.

Identification: This is among the slimmest and most beautiful of mackerels. The head is comparatively small and the body rather compressed. The color is silvery with blue-green above and large yellow spots on the sides.

Habits: This fish is found inshore in shallow waters in late summer, when it

may be commonly seen leisurely swimming singly or in small pods. The authors have seen them in shallow coral areas in August. They school more densely in deeper waters. The spawning occurs offshore in late spring and early summer. The eggs are floating and very numerous. Menhaden and other small fishes are its principal food.

Similar Species: The Mexican sierra, *Scomberomorus sierra*, is very similar to the Atlantic form. It is common in the tropical eastern Pacific and reaches north to Baja California and rarely to San Diego.

The cero (painted mackerel, kingfish, pintado), *Scomberomorus regalis*, is found from Cape Cod to Brazil and is not generally common. It has the soft dorsal fin inserted directly above the anal (in the Spanish mackerel the soft dorsal is a little ahead of the anal) and a solid or broken yellowish-brown lateral stripe. It tends to be a bit larger than the Spanish mackerel but is otherwise very similar.

The king mackerel (cero, cavalla, kingfish, etc.), *Scomberomorus cavalla*, is the largest of its genus, weighing up to 50 pounds. It is completely silvery, with no markings, and has the lateral line abruptly decurved under the soft dorsal fin. It is typical of the West Indies and reaches north to Cape Hatteras.

The wahoo (kingfish, peto), *Acanthocybium solandri*, has a very wide tropical distribution. It is found in the Western Hemisphere north to Maryland in the late summer, and is also found off the western coast of Mexico, but it is found chiefly in the West Indies. The body is long and slim and crossed by dark vertical bars its whole length. Because of the large size, averaging 25 to 45 pounds and reaching 6 feet and 133½ pounds, and the beaklike snout set with large teeth, it has been confused with the barracuda.

OCEANIC BONITO (SKIPJACK): *Katsuwonus pelamis—Color Plate 2*

Size: Up to 2½ to 3 feet.

Weight: Averages 4 to 5 pounds. Up to 25 to 35 pounds.

Distribution: Cosmopolitan in warm seas. North on our coasts to Cape Cod and Point Conception.

Identification: The belly has a series of dark longitudinal stripes. There is a corselet of scales around the body near the pectoral fins (as is common in many of the tunalike fishes).

Habits: This is the most likely to be encountered and one of the smallest of the tunalike fishes, many of which are practically cosmopolitan in warm seas. All are exceedingly swift and voracious, and are found principally offshore. These fishes travel in moderately large schools that are constantly on the move. The nature and causes of their movements are poorly understood. The chief food of all tunalike fishes consists of smaller oceanic schooling fishes. The oceanic bonito is fond of eating flying fishes.

Similar Species: The confusing array of oceanic tunalike fishes is best divided into three groups: (1) tunas, *Thunnus* and *Neothunnus*, (2) bonitos, *Sarda*, and (3) albacores, *Germo*. The tunas are huge, reaching 1,500 pounds, and are usually plainly colored. The bonitos are smaller, rarely over 3 feet, and are obliquely striped on the back (stripes run up and back from the mid-body). Albacores attain 80 pounds in weight and have very long, sickle-shaped pectoral fins that reach back to behind the origin of the anal fin.

ANSCOCHROME-BAHAMAS

Branching antler coral sometimes forms dense forests and affords a home for many fishes including this sergeant major.

Fan worms make their homes in massive corals like this brain coral, one of the foundation stones of reefs.

ANSCOCHROME-BAHAMAS

ANSCOCHROME-BAHAMAS

These plant-like animals, red sponges, hydroids, and gorgonians, live by filtering plankton from the sea.

A flower-like anemone, nestled between a sponge and a coral, waits for some unlucky, small fish to wander into its poisonous, stinging tentacles.

ANSCOCHROME-BAHAMAS

The false albacore, *Katsuwonus alletteratus,* belongs to none of these groups, but is very closely related to the oceanic bonito. It has no ventral stripes.

CUTLASS FISHES: Family Trichiuridae

These degenerate eellike fishes are like mackerels in the appearance of the head, but otherwise are very odd. The silvery to silvery brown color, the general lack of fins, and the scaleless body identify them. Cutlass fishes can move swiftly and strongly but usually keep to the bottom.

They feed voraciously on other fishes. They are generally distributed in all tropical seas and are excellent food.

CUTLASS FISH (SCABBARD FISH, SILVERFISH, MACHETE): *Trichinrus lepturus*

Size: Up to 5 feet but usually smaller.

Distribution: West Indies to Virginia. West Coast north to southern California.

Identification: Same as for the family.

Habits: The authors have never seen this fish, but suspect that it might be a very nasty customer to handle. Little seems to be known of it. It is not common over most of its range but may be fairly plentiful near Puerto Rico where the name "machete" is used for it.

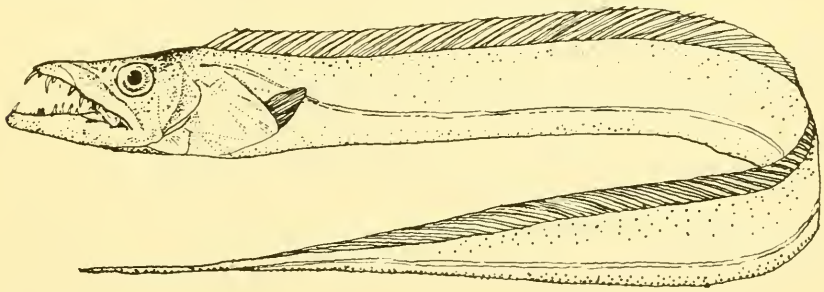


Fig. 107. Cutlass fish.

SPEARFISHES: Family Istiophoridae

All of the several species of spearfishes, sailfishes, marlins, and the related swordfishes are very large, very swift, pelagic fishes of wide distribution in tropical and warm temperate seas. Their speed and endurance is as great as that of any fish.

All have a long round spear or flat sword projecting out from the snout and all are toothless or practically so. The dorsal fin of all except the swordfish can fold down into a dorsal furrow. All are fish-eaters on the medium-sized schooling kinds such as herrings or mackerel. It would be of great interest to see one of these under water, though this would not be without its dangers; there is some evidence that these very powerful fishes attack boats and sharks with their spears when molested. None of them seems to be exactly even-tempered, and they may even be listed as dangerous fishes. These are rather mysterious fish even though they are not rare and are even common in places. Their manner of feeding seems to be to approach a school of small fishes and to slash at it with their spear. Then the stunned and mutilated prey are eaten at leisure.

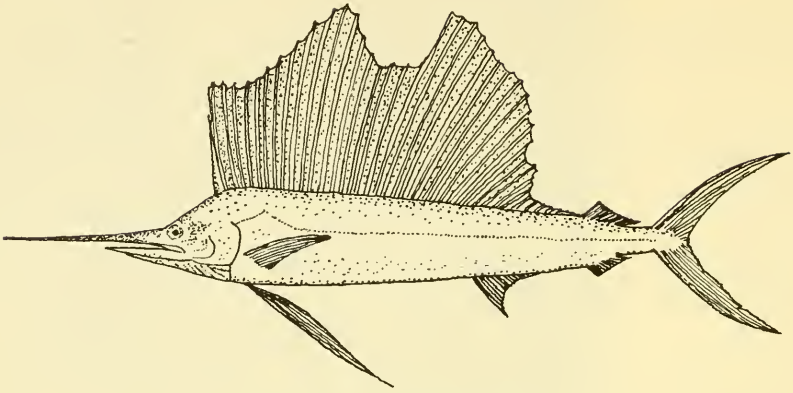


Fig. 108. Atlantic sailfish.

Spearfishes are solitary or may travel in pairs. The predominant color is a beautiful silvery blue, frequently with vertical stripes. The colors become more vivid when the fishes are fighting or dying.

ATLANTIC SAILFISH: *Istiophorus americanus*

Size: Averages 6 feet. Up to 8 feet.

Weight: Averages 30 to 50 pounds. Up to 123 pounds.

Distribution: West Indies to Florida. Straggles to Cape Cod.

Identification: The saillike fin makes this fish unmistakable. When traveling speedily through the water this fin is folded back in a slot on the back. The slim body and small size (for spearfishes) then becomes the best means of identification. The ventral fins are long.

Habits: Sailfishes are the most common, the smallest, and the most spectacular and beautiful of the spearfishes. There is a good chance of seeing them under water for they come quite close to shore. Often, they travel in pairs. The sail is always raised when they fight on the line and presumably also when they are otherwise annoyed or excited. The purpose of such a large fin is not known. Sailfishes and other spearfishes like to bask at the surface.

Similar Species: The Pacific sailfish, *Istiophorus greyi*, grows to a larger size than the Atlantic sailfish, averaging 100 pounds and reaching 275 pounds. It is found north to southern California.

There are several marlins which look like sailfishes, but none of them has the very high saillike dorsal fin. The blue marlin, *Makaira nigricans*, is a bulky fish with no visible lateral line. It reaches 750 pounds but averages 300 to 400 pounds and is found in the warm Atlantic. It is not very common. The white marlin, *Makaira albida*, is another warm Atlantic species of rather small size (up to 150 pounds) and comparatively light coloration. It has a conspicuous lateral line. The striped marlin, *Makaira mitsukurii*, is the only striped Pacific species and is the most vividly striped of all spearfishes. It is of the warm Pacific and reaches huge size, weighing up to over 1,000 pounds, and reaching a length of 14 feet.

The swordfish, *Xiphias gladius*, is of the family Xiphiidae, and its distribution is world-wide in all warm seas. It reaches 600 pounds (Norman and Fraser, 1938, list it as the largest marine fish—up to 20 feet long and 1,000 pounds) and is

exceedingly swift and powerful. It has a huge, flat sword that is over one third of its total length. The coloration is grayish to brown, and the shape of the body is reminiscent of a mackerel shark, especially because of the high dorsal fin placed just behind the head. The swordfish is by no means to be trusted. It has been known to drive its sword through the bottoms of boats, though tales of its ferocity are usually exaggerated.

JACKS: Family Carangidae

This is primarily a tropical family. It is composed of a large assemblage of predacious species most of which are deep-bodied, compressed silvery fishes, more typical of inshore waters than are the true mackerels. There are a great number of very similar species. Most school when young but are found in small pods or even singly as adults. These swift fishes often have the posterior part of the lateral line reinforced by hard, bony scutes. The scales are small. On the whole, one is strongly reminded of the true mackerels, but some of the adaptions for speed, such as the bullet-shaped, fusiform body have been lost. Almost all jacks have two short spines preceding the anal fin. Their distribution is world-wide in warm seas, and most are excellent food fishes. They are liable to be stand-offish with the swimmer. It is unfortunate that in this prominent group the common names are extremely confused. On top of that, many common species are difficult to identify, even for the ichthyologist. The group is arranged below starting with the species that are most like the mackerels and progressing outward from these toward the deeper-bodied, more compressed species.

LEATHER-JACKET (ZAPATERO): *Oligaplites sorus*

Size: Up to 1 foot.

Distribution: Both coasts of tropical America. North to San Diego and New York.

Identification: Compressed body. There are five dorsal and two anal spines before the soft dorsal and anal fins. These fins reflect each other in size and shape and are broken up into finlets posteriorly. The color is bluish to whitish on the sides and bluish to bright green above.

Habits: This is an inshore predator on small fishes. Its sharp dorsal and anal spines are capable of inflicting injury, but they are not poisonous. It flops about vigorously when caught and should not be handled with bare hands.

YELLOWTAIL JACK (AMBERJACK, CORONADO): *Seriola dorsalis*–*Color Plate* 2

Size: Averages 2½ feet. Up to 5 feet.

Weight: Averages 10 pounds. Up to 60 pounds.

Distribution: Monterey Bay to the Gulf of California and south to Chile.

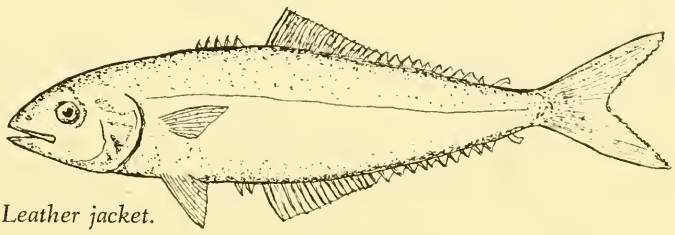


Fig. 109. Leather jacket.

Identification: The mackerellike body is not very compressed. The spiny dorsal is small and the anal is much shorter than the soft dorsal fin. A prominent wide yellow stripe runs along the side and onto the tail.

Habits: This large and speedy predator travels solitarily, in small pods, or in schools near reefs or over deeper water on the prowl for the small fishes which are its prey. It has the habit of driving its prey into shallow water near shore. It spawns in the summer, probably at sea.

Similar Species: There are several members of this genus, all of which are best recognized by the general silhouette and fin pattern which they all have in common. The great amberjack, *Seriola lalandi,* is also called the horse-eye bonito and has the distinguishing mark of many of this genus—the dark stripe running diagonally through the eye from the base of the spiny dorsal to the upper lip. It ranges from Cape Cod to Brazil, being most common in the West Indies.

The rainbow runner, *Elagatis bipinnulatus,* has the shape and fins of the *Seriola* species but has a very striking pattern consisting of four beautiful iridescent longitudinal stripes of dark blue, light blue, yellow, and again light blue from back to stomach in that order. It is not a common fish, but it is pelagic in all tropical seas, being found north to New York and to southern California in summer. It reaches a weight of 12 pounds.

PILOT FISH: *Naucrates ductor*

Size: Up to 2 feet.
Distribution: Offshore in all warm seas.

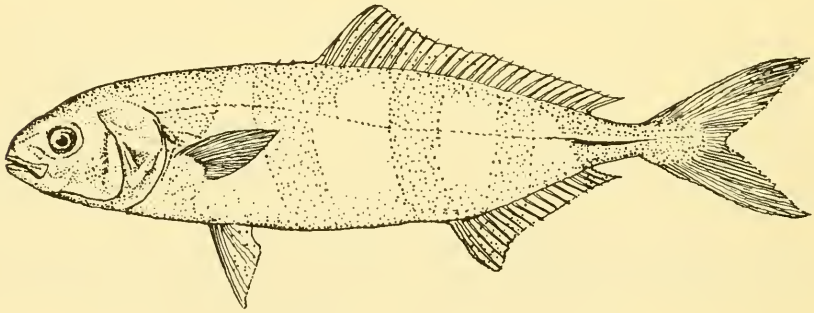


Fig. 110. Pilot fish.

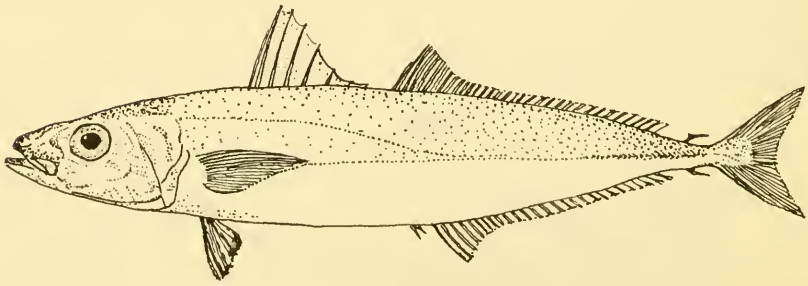


Fig. 111. Round scad.

Identification: This fish is characterized by wide, dark, vertical crossbands. The spiny dorsal is very reduced. The anal fin is much shorter than the soft dorsal.

Habits: This is the fish that is commonly seen following sharks and vessels at sea. It does not lead sharks to food but probably only hangs around them for the scraps of the table. It is too fast and agile for the sharks to catch. The eggs are laid at sea in the summer.

Similar Species: The banded rudderfish, *Seriola zonata,* is banded while young and replaces the pilot fish in following sharks and vessels inshore. It has a small spinous dorsal as do other members of the genus *Seriola.*

ROUND SCAD: *Decapterus punctatus*

Size: Up to 1 foot.

Distribution: Cape Cod to Brazil.

Identification: The body shape is slim and round like that of a mackerel. The posterior lateral line is well armed with bony scutes in this genus. The dorsal and anal fins are followed by a finlet in the true scads and the soft dorsal and anal are of similar length.

Habits: The several species of small scads school in- and off-shore. They feed mostly on small invertebrates. These are among the smallest fishes of this family.

Similar Species: The Pacific counterpart of the scads is the saurel (rough scad or California horse mackerel), *Trachurus symmetricus.* Its entire lateral line is armed with large scutes from head to tail, this being the only jack to show such a feature. Otherwise it is like a typical scad, although of somewhat stouter shape. It reaches 2 feet but is mostly much smaller. The range is from San Francisco southward through the tropics.

There is an Atlantic representative of the rough scad, and there are also several species of *Decapterus* on the Atlantic and Pacific Coasts, which are difficult to separate from the member of that genus already described. The goggle-eyed scad or big-eyed scad, *Trachurops crumenopthalmus,* is much like *Decapterus* species, but it has a huge eye and a slightly stouter shape (like the rough scad). It grows to 2 feet and is found on both coasts north to Cape Cod and Cape San Lucas.

JACK CREVALLE (COMMON JACK): *Caranx hippos*–*Color Plate 2*

Size: Up to 2½ feet or larger.

Weight: Averages 2 to 5 pounds. Up to 20 pounds or more.

Distribution: Cape Cod to Brazil. Chiefly West Indies in the Atlantic. In the Pacific, from Gulf of California southward.

Identification: With this fish and others of this genus there is a very definite tendency toward (1) the development of the high forehead and back, (2) decurved lateral line armed posteriorly with bony scutes, (3) deep, compressed body, and (4) soft dorsal and anal fins of very similar size and shape–features that we think of as being typically jacklike. The species are many and extremely difficult to identify. This species has a particularly blunt forehead and also possesses a dark spot on the rear edge of the operculum.

Habits: This fish is characteristic of inshore and offshore waters, chiefly around coral areas. When young, this fish and others of its genus school. As an adult, it is mostly seen in small pods. It is largely a surface predator on fishes.

Similar Species: The members of this genus are so confusing that we must refer the reader to other works for the details. Only a few of the common relatives can be mentioned here.

The little skipjack, *Caranx ruber* (*fig. 104*), is the species most commonly seen by swimmers in the West Indies. It has a dark dorsal stripe extending down the back and onto the lower tail lobe. This little jack reaches the length of a foot. It is often seen scampering after sting rays and barracudas. These larger fishes do not seem to bother this speedy little fellow.

The blue runner (jack crevalle, hard-tailed jack), *Caranx crysos,* reaches almost 2 feet in length and is very similar to the common jack crevalle, having the opercular spot. It differs chiefly in its lower forehead, smaller size, and more inshore habits. It is chiefly West Indian and ranges north to Cape Cod.

The yellow jack, *Caranx bartholomaei,* has a deep, golden-tinged body and no opercular spot. It reaches a size of up to 2 feet, but is usually seen smaller and is found from the West Indies and rarely to Cape Cod.

The horse-eye jack, *Caranx sexfasciatus,* is also called "yellow jack" and is another deep-bodied species. It has a small opercular spot, deep body, and very large eyes. It is common in all tropical seas reaching north to Virginia and to northwest Mexico. It reaches two feet in length.

The green jack, *Caranx caballus,* is very much like the blue runner but tends to be greener. It is found from San Pedro, California, southward. It reaches 15 inches in length.

The little bumper, *Chloroscombrus chrysurus,* is similar to the typical jacks, but it has no scutes on the lateral line, and the curvature of the belly is greater than that of the back. It reaches only 10 inches and feeds mostly on plankton inshore and offshore. The young frequently take refuge under jellyfishes. It ranges from Cape Cod to Brazil, is chiefly West Indian, and has a West Coast representative of western Mexico, the xurel de castilla, *Chloroscombrus orgneta.*

PALOMETA (OLDWIFE, ALEWIFE, GAFF-TOPSAIL POMPANO): *Trachinotus palometa*

Size: Averages 1 foot.

Weight: Averages 1 pound. Up to 4 pounds.

Distribution: Virginia to Argentina. Most common in the Caribbean.

Identification: In members of this genus, the body is very deep and compressed, the mouth small, the snout rounded, the color silvery (frequently with yellow about the head, belly, and tail), and the spiny dorsal fin very reduced. The first few soft dorsal and anal rays of this genus are usually long, but in this species they are exceptionally so. This species also has four dark vertical bars. The name "pampano" (anglicized, "pompano"), is a Spanish word for "grape leaf" and refers to the shape of the body.

Habits: Pompanos are shallow-water tropical fishes. The species of the genus are frequently found inshore in surf and about coral areas as well. The larger ones are found in deeper waters frequently, but as a whole, these fishes keep more to inlets or sand and mud bottoms than do the typical jacks. Almost all of them travel in small schools or pods. Because of the small mouth, the food is limited to small fishes, crustaceans, and molluscs.

Similar Species: This is another large and confusing genus which contains some of the finest food fishes that swim.

The pompanito, *Trachinotus rhadopus*, is very similar to the palometa and is found from the Gulf of California southward.

The common pompano, *Trachinotus carolinus* (*fig. 112*), is a much sought-after food fish. It has a prominent, yellowish belly, throat, and head. It is quite as deep-bodied as the palometa and has no vertical bars. The maxillary bone just reaches the front part of the eye. The fish reaches 18 inches in length and 7 to 8 pounds and is most common off the Gulf States and Florida around surf and inlets over soft bottoms. This fish is reported by Phillips (1952) to indulge in a strange "flight." The fish sails through the air on its side, head slightly elevated, looking like a sailing paper plate.

The permit (great pompano, alewife), *Trachinotus goodei*, reaches large size, up to 3½ feet and 47 pounds, but averages 20 pounds. It is very similar to the common pompano, separated from it by having the maxillary bone extended past the pupil of the eye and by rather technical features, such as its possession of

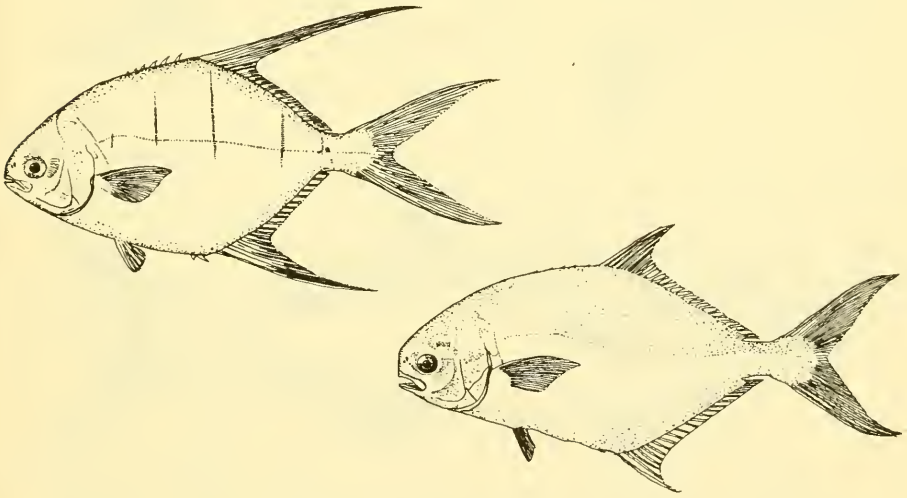


Fig. 112. Palometa (upper left) and pompano (lower right).

nineteen to twenty soft dorsal rays and seventeen to nineteen anal rays, in contrast to the common pompano's twenty-five and twenty-two respectively. It is not often found in the same waters as the common pompano, being mainly West Indian.

The round pompano (permit), *Trachinotus falcatus*, is very round and deep-bodied, as is the palometa, and has a rounded profile. It is found in common pompano waters, but it is also found from Cape Hatteras south to Brazil.

The African pompano, *Hynnis cubensis* (*Hynnis hopkinsi* in the Pacific), is a rather rare offshore fish of the West Indies and is also found from Mexico to Panama. It reaches 30 or more pounds and has scutes on the posterior lateral line. The color is a plain bluish silver, and the shape is like the jack cravalle, but the fins are like those of the pompanos.

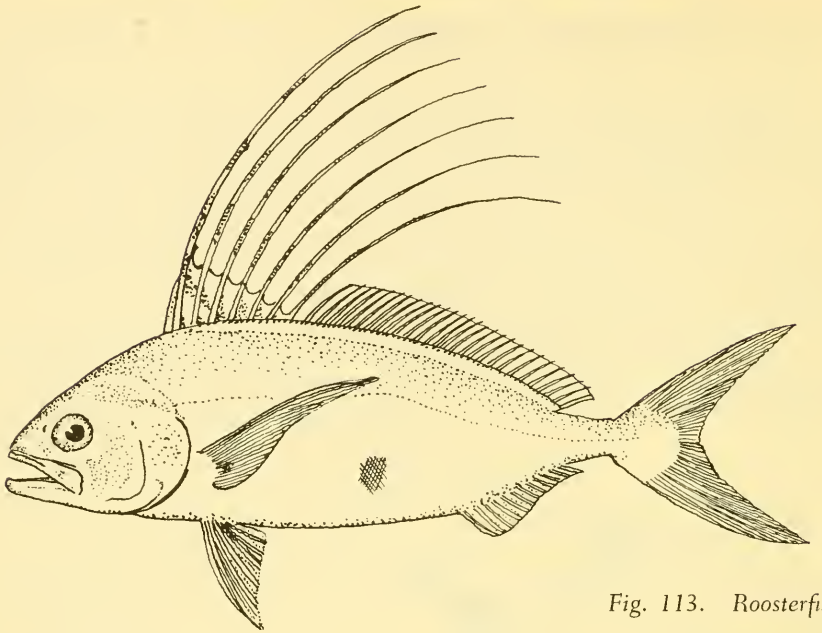


Fig. 113. Roosterfish.

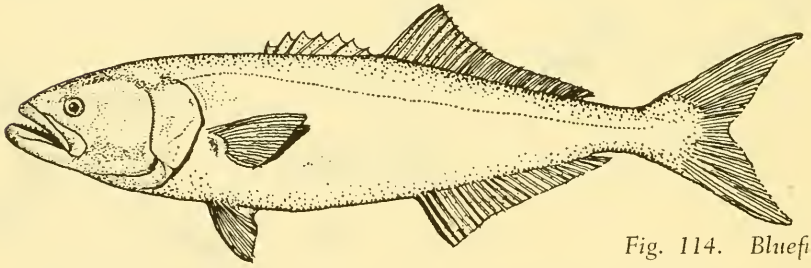


Fig. 114. Bluefish.

LOOKDOWN (HORSEHEAD, MOONFISH): *Selene vomer—Color Plate 2*

Size: Averages 7 to 8 inches. Up to a little over a foot.

Distribution: Cape Cod to Brazil. Baja California to Peru. Most common in the tropics.

Identification: This most compressed and deep-bodied of all jacks is easily recognized. The pearly, iridescent colors on the wafer-thin body reflect all possible delicate shades of the spectrum.

Habits: This is a schooling fish which is most common over sandy shores. It feeds on all sorts of small fishes and invertebrates. At times, it takes refuge in pilings, under bridges, around reefs, but it seems to be most common in rather open water.

Similar Species: Only the moonfish, *Vomer setapinnis*, could be confused with this fish. The shape, size, and color are the same, but the soft dorsal and anal fins are not extended as they are in the lookdown. It is found from Maine

to Brazil and from Cape San Lucas to Peru, but it is chiefly tropical. The young are common in the fall north to New York (via the Gulf Stream).

THREADFISH: *Alectis ciliaris*—*Color Plate 2*

Size: Up to 7 inches including fins. Body usually not larger than 2 inches in diameter.

Distribution: Cosmopolitan in tropical seas. Drifts north in warm currents.

Identification: The dark bands on an intensely silver body and long dorsal and anal fins identify it.

Habits: This is a somewhat mysterious little fish. It is much more common beneath the surface than reported in most books, though it is by no means really plentiful. In the young the dorsal and anal fin extensions are like bands and are three times the body length. As the fish sits under ledges in reefs, these fins ripple to create a truly exquisite picture. As the fish grows older, the fins wear down and become shorter and thinner. It is not a timid fish and may be approached quite closely in contrast to most jacks.

PAPAGALLOS: Family Nematistiidae

ROOSTERFISH: *Nematistius pectoralis*

Size: Up to 3 to 4 feet.

Distribution: Gulf of California to Panama.

Identification: The extremely long dorsal spines are unmistakable. The color is a beautiful, iridescent, silvery blue, darker on the back.

Habits: This is a very beautiful and stately fish which swims singly inshore or offshore. It is predacious and very much like the jacks in habits. The dorsal is held erect only when the fish is excited, lying in a groove on the back at other times.

BLUEFISH: Family Pomatomidae

BLUEFISH (TAYLOR, SNAPPER): *Pomatomus saltatrix*

Size: Up to 4 feet or more.

Weight: Averages 1 to 5 pounds. Up to 25 pounds or more.

Distribution: Cape Cod to Venezuela and most warm seas, but not found off Europe or the West Coast of North America. Very erratic in appearance and abundance.

Identification: Basslike shape and bluish color. Large mouth and head. There are no scales on the lateral line.

Habits: This living chopping machine is one of the most voracious of all fishes. Schools travel constantly, destroying schools of fishes in their way. They are common off channels and outside beaches in the warmer months, but their continual movement makes their appearance extremely variable. Jordan (1908) gives a good account of this species. Favorite foods are weakfish and the herrings. Bluefish spawn in the spring and early summer. Not much is known of its habits even though much has been written of it and it has been a favorite of anglers and gourmets for years.

SERGEANT FISH: Family Rachycentridae

COBIA (SERGEANT FISH, CRAB-EATER, CUBBY YEW): *Rachycentron canadus*

Size: Up to 5 feet.

Weight: Averages 10 to 15 pounds. Up to 125 pounds.

Distribution: Nearly cosmopolitan in warm seas, gets as far north as the Chesapeake and straggles to Cape Cod. Most common in the Gulf of Mexico off Mississippi. Not found on the Pacific Coast.

Identification: The elongate shape, longitudinal stripe on the midline from the eye to the tail, and the brown body are unmistakable.

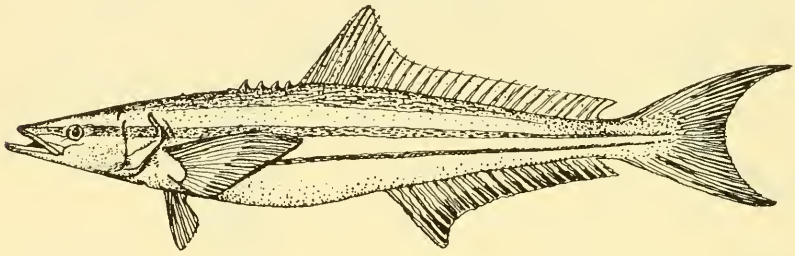


Fig. 115. Cobia.

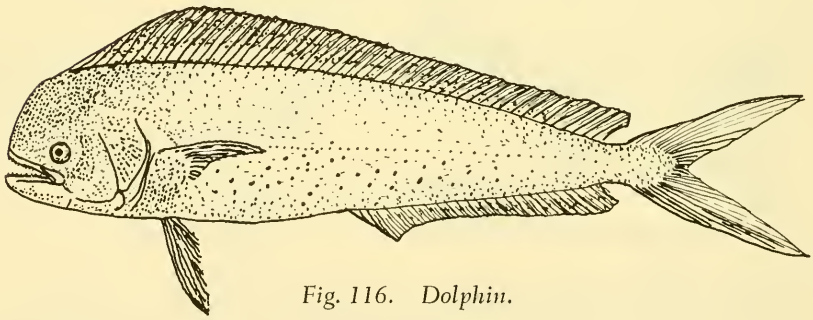


Fig. 116. Dolphin.

Habits: This is not a particularly common fish, but it is not rare if one looks in the right spots. Its favorite haunts are offshore near channel markers, buoys, lighthouses, and rocks. Upon occasion it has been known to travel with king mackerels, *Scomberomorus,* and manta rays. It is a swift fish and will pursue menhaden, bluefish, and other schooling forms, but prefers to feed on the bottom on crabs and flatfish. It is found in schools, groups, or alone.

MAN-OF-WAR FISH: Family Nomeidae

MAN-OF-WAR FISH: *Nomeus gronovi—Color Plate 10*

Size: Up to 8 inches.

Distribution: Cosmopolitan in warm seas. Rather common in the Gulf Stream.

Identification: This fish can be recognized by its exceedingly large ventral fins and a mottled black-and-silver pattern.

Habits: This is a pelagic species usually found in the powerful company of the Portuguese man-of-war, *Physalia.* This fish is not immune to the poison of the jellyfish, but somehow has learned to skillfully dodge the tentacles as it runs in among them for protection against larger fishes. It eats small invertebrates mostly and comes inshore only when the man-of-war drifts in. Not much is known of it.

DOLPHINS: Family Coryphaenidae

There are only two species, both very similar.

DOLPHIN (DORADO): *Coryphaena hippurus*

Size: Reaches 6 feet.

Weight: Averages 5 pounds. Reaches 35 pounds.

Distribution: Cosmopolitan in warm seas. North to Long Island in the Gulf Stream. Not very common in the eastern Pacific.

Identification: The shape and the soft dorsal fin, as illustrated, are distinctive. In life, the colors are a beautiful series of changeable blues, greens, yellows, and silver. The body is very streamlined and compressed. In old males, the foreheads become very high as shown in the drawing.

Habits: The dolphin is one of the fastest fishes, capable of spurts of up to 50 mph. It prefers blue water and is pelagic on the surface, feeding avidly on small fishes, especially the flying fish. Large ones usually travel in pairs, but small ones school.

Similar Species: The dolphin is often confused with the little dolphin, *Coryphaena equisetis,* which reaches only 2½ feet and never has a high forehead. The only way to separate the two is by comparing the number of lower fin rays (little dolphin: anal, 24 to 26, dorsal, 51 to 55; dolphin: anal, 26 to 30, dorsal, 55 to 65). The little dolphin is also cosmopolitan in warm seas, and is the most common dolphin from southern California southward.

HARVEST FISHES: Family Stromeidae

These are plankton-feeding, silvery, pelagic, schooling fishes found in all warm seas. All have a symmetrically round and deep body and lack ventral fins. When small, these fishes have the habit of swimming under the bells of large jellyfishes, but sometimes they get careless, bump into a tentacle, and are killed and eaten by the jellyfish.

BUTTERFISH (DOLLARFISH, HARVEST FISH): *Poronotus tricanthus*

Size: Averages 7 inches. Up to 1 foot.

Distribution: Nova Scotia to Cape Hatteras. Deep water to Florida.

Identification: This fish is compressed and silvery.

Habits: This is a summer fish, schooling near shore at that time, appearing and disappearing at about the same time as the common mackerel, *Scomber.* The pelagic eggs are released in June and July.

Similar Species: The harvest fish, *Peprilus alepidotus,* is of similar habits and size as the butterfish, but it is much deeper of body, being nearly round when viewed from the side. It is known from Cape Cod to Brazil, becoming more common as the butterfish becomes rare to the south. It sometimes occupies the area under the bell of the Portuguese man-of-war.

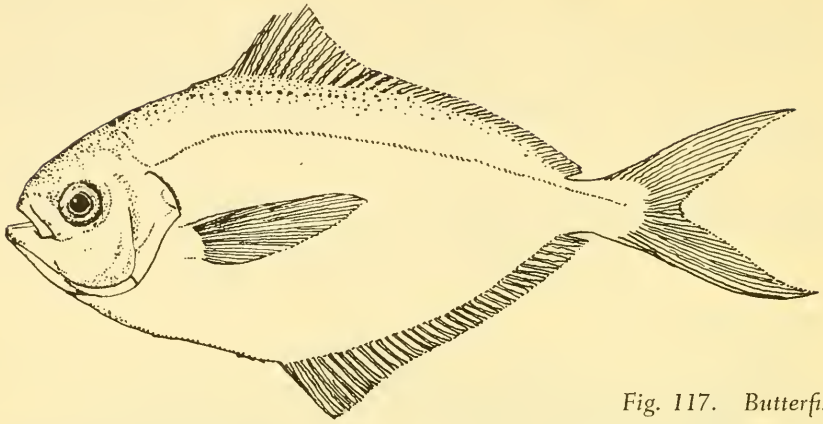


Fig. 117. Butterfish.

The large pomfret, *Brama rai*, family Bramidae, is very similar in shape to the butterfish but is of dusky coloration and has small ventral fins. It reaches 2 to 4 feet in length and is rare in the Atlantic but not uncommon in the Pacific from southern California southward.

The California pompano, *Palometa simillima*, is found from Puget Sound to southern California. It is sought for food and has a similar appearance to the butterfish.

Perchlike Fishes: *Suborder Percoidei*

The perchlike fishes, often called "typical fishes," are the principal inshore predators, conforming to the preconceived notion of a fish more than any other group. This is a group that is even more complex than the mackerellike fishes. Most are not of pelagic habits as mackerellike fishes tend to be, and they are more familiar to the swimmer than the mackerels. Therefore, they may not offer as much trouble as mackerels in identification.

These fishes are closely related to the mackerellike fishes, and, with them, make up the bulk of spiny-rayed fishes. The fins are very spiny, and the tail is not constricted at its base as in the mackerels. The scales are rather large and the colors extremely variable, including all the shades of the spectrum, being silvery in only a few groups.

There are large numbers of these important and common fishes in all seas. The greatest diversity is in the tropics. The various families are anatomically very similar to each other and are separated by ichthyologists on a technical basis. Even though the field study of fish habits is in its infancy, certain characteristics—their habits, general silhouette, and movements—are known that serve to separate the families. The swimmer should look for and learn to use his own clues, however.

CARDINAL FISHES: Family Cheilodipteridae

These are large-eyed, usually red, little fishes, typical of coral reefs of all tropical seas. These are the only small red perches in which the spiny and soft

dorsal fins are widely separate from one another. One peculiar habit usually identifies them. These little fishes are most often seen in the company of large conchs or other shellfish, whose living shells they use for retreat. Cardinal fishes are largely nocturnal and some carry their eggs in their mouths for incubation.

CONCHFISH: *Apogonichthys stellatus–Color Plate 3*

Size: Up to 2 inches.
Distribution: West Indies to Florida.
Identification: This is one of the smallest cardinal fishes, and has exceptionally large ventral fins.
Habits: Among the cardinal fishes, this one in particular is addicted to using the mantle cavity of the large queen conch, *Strombus gigas*, for retreat. It is also known to use the cavities of sponges for the same purpose. Its food consists of small invertebrates.

SNOOKS: Family Centropomidae

There is but one genus containing a few very similar species, all found in the American tropics.

SNOOK (SERGEANT FISH, PIKE, ROBALO): *Centropomus undecimalis*

Size: Up to 5 feet.
Weight: Averages 4 to 8 pounds. Up to 60 pounds or more.
Distribution: West Indies to Florida. Baja California to South America.
Identification: Pikelike build and a black lateral line which extends onto the tail. The color is straw-brown.

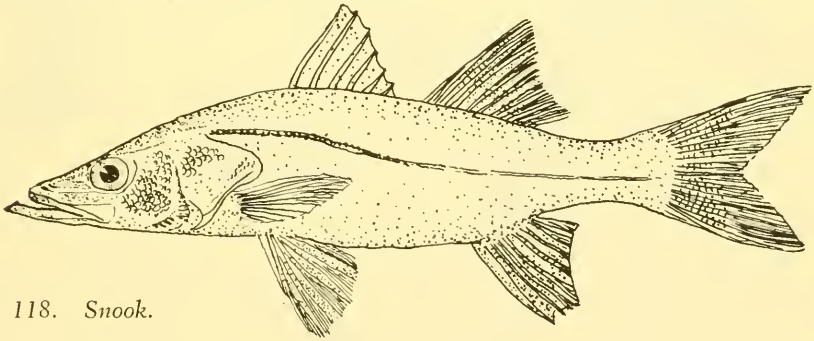


Fig. 118. Snook.

Habits: This is a large, swift, predatory fish of shallow waters. It especially likes brackish waters of mangrove areas and river mouths, sometimes traveling in small schools. Its food, taken largely at dusk or at night, consists of small fish and crustaceans.

SEA BASSES: Family Serranidae

The four hundred to five hundred species of sea basses found the world over in warm temperate and tropical seas offer some of the most rewarding experiences under water. The large tropical species (groupers), if not frightened because of spearfishing pressures, are fearless and very easy to train by chumming. After only a few feedings, large groupers will follow the swimmer

around like a faithful dog. Even if not so trained, these fishes are engaging and fearless fish.

Basses are almost insatiably curious. Bright objects, like polished metal or mirrors, serve to attract them very close to the swimmer. The voracity of basses is almost legendary. They rush at their prey by sudden movements of the large pectoral and tail fins. As the mouth opens, a suction is created, water passing in the mouth and out the gills, and the prey is drawn in. The many small teeth in the jaws and on the tongue and palate hold the prey, which is swallowed whole. The food varies from fishes to crustaceans and other invertebrates. Groupers are fond of octopuses as food.

Some basses reach huge size, having mouths into which a man could fit his head and shoulders. Their size and fearlessness could make these fellows rather dangerous, although one could probably not call any of them, with the possible exception of jewfishes, naturally pugnacious if left unmolested. Most basses travel singly and "home" to very definite holes in rock or coral, not straying far from a single spot throughout their lives. Basses are variable in almost every respect, color, size, pattern, etc., but they are best separated from near relatives by the rather massive head with its very capacious, thick-lipped, underslung lower jaw, the anal fin which is a little shorter than the soft dorsal,

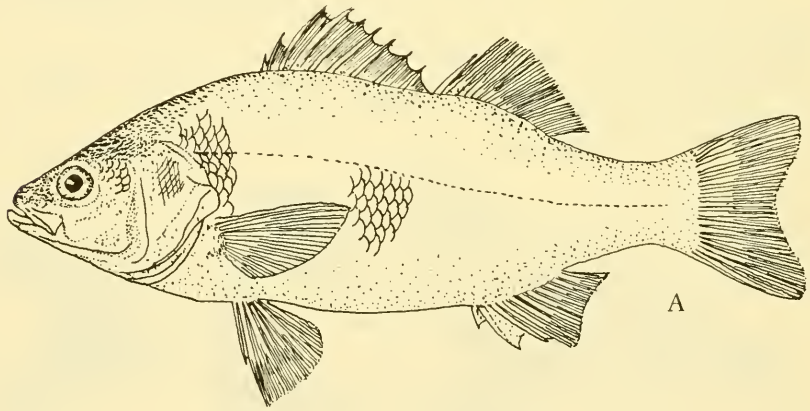


Fig. 119. White perch.

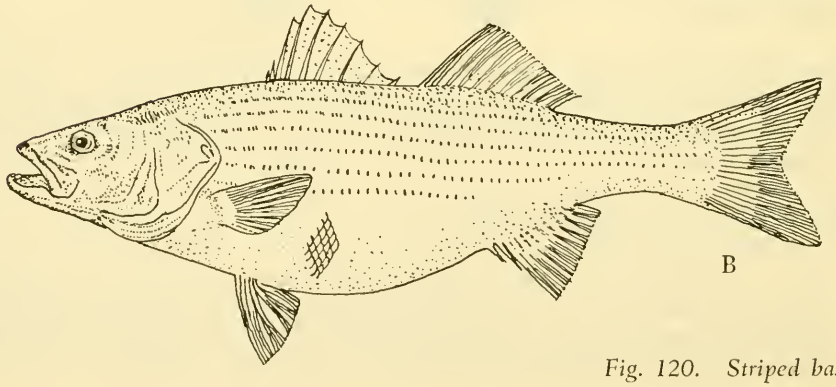


Fig. 120. Striped bass.

and the solitary, inshore habits. There are exceptions to all these rules, but the exceptions are not hard to identify. Most of the confusion arises with the great mass of typical sea basses, the groupers or rockfishes, whose common names and coloration are maddeningly variable, and also with the many species of midget basses. Color is, on the whole, not a good species indicator here. Better are silhouette, habits, color pattern, and distribution.

WHITE PERCH (SILVER BASS): *Morone americana*

Size: Averages 10 inches. Up to 15 inches.

Weight: Up to 2 to 3 pounds.

Distribution: Nova Scotia to South Carolina. Most common near the Chesapeake.

Identification: The most unbasslike bass in appearance and habits. It is compressed and deep-bodied with whitish, silvery, or olivaceous sides and faint longitudinal stripes. The spiny dorsal fin just reaches the soft dorsal.

Habits: This is really a fresh-water fish. It is not found far from the brackish waters of bays and river mouths and goes upriver to breed, frequently becoming landlocked. It schools in very large numbers and eats small fishes and crustaceans.

STRIPED BASS (ROCKFISH): *Roccus saxatilis*

Size: Commonly to 3½ feet. Recorded to 6 feet.

Weight: Averages 1 to 10 pounds. Commonly 25 to 40 pounds. Recorded to 125 pounds.

Distribution: St. Lawrence to Florida. Most common from Cape Cod to Cape May, New Jersey. Introduced on the West Coast in 1879 and now found from southern California to the Columbia River.

Identification: The spiny dorsal fin does not reach the soft dorsal. The color is a brassy silver with seven or eight longitudinal black stripes.

Habits: This anadromous fish is found singly or in small to large schools around rocky shores, bays, beaches, and the mouths of rivers. Since it ascends rivers to spawn, it has suffered from pollution and also from overfishing, but is still rather plentiful. Before 1900 up to thirty-eight thousand pounds of stripers, many over 60 pounds, were landed in one haul of the nets. The spawning season is in the spring. Nonadhesive, heavy eggs, up to 2 to 3 million per female, are laid in large rivers. The striped bass is a voracious feeder on fish and large crustaceans.

CALIFORNIA KELP BASS (ROCK BASS, CABRILLA): *Paralabrax calthratus*

Size: Averages 1½ feet. Up to 20 inches.

Weight: Averages 3 to 4 pounds. Up to 5 pounds.

Distribution: San Francisco to Cape San Lucas.

Identification: The dorsal spines are long anteriorly. Color is grayish green with broad, dusky, vertical bars. There are spots in similar species, but not in this one.

Habits: This is a fish of the kelp beds and rocks, being one of the most common rather large fish found there. It is carnivorous on smaller fishes. The kelp bass strays over sandy bottoms and spawns in the summer.

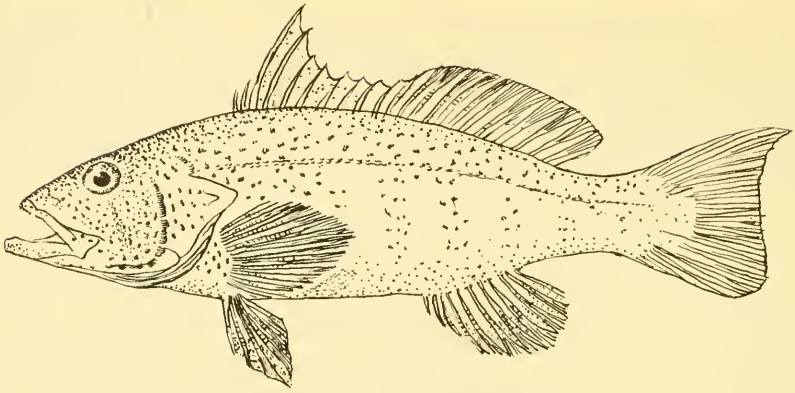


Fig. 121. Spotted kelp bass.

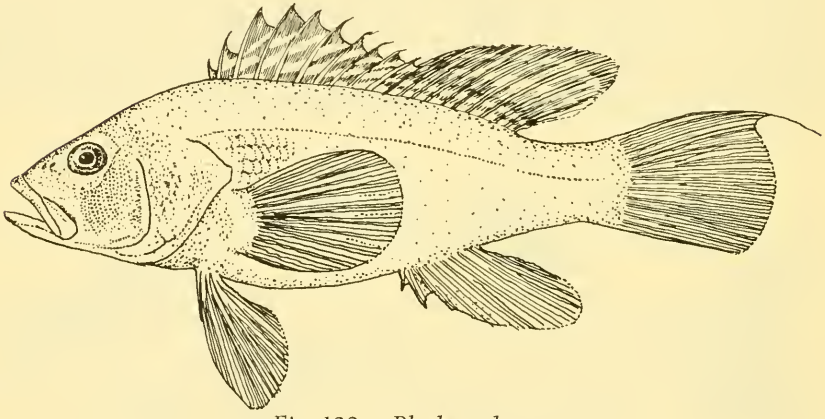


Fig. 122. Black sea bass.

Similar Species: There are eight species of this genus, all of which are of the eastern Pacific. Most are spotted as shown in figure 121.

BLACK SEA BASS: *Centropristes striatus*

Size: Large at 18 inches. Up to 22 inches.

Weight: Averages 1 to 2 pounds. Large at 4 pounds. Up to 8 pounds.

Distribution: Cape Ann to north Florida. Most common from Cape Cod to Cape Hatteras.

Identification: The color is dark gray with blotchy markings and light spots on the scales. The top ray of the tail fin is elongated to form a filament.

Habits: This is a voracious but sluggish bottom fish most common around wrecks, pilings, or rocks at a depth of about 100 feet. It eats a wide variety of fishes, crustaceans, and squids. In habits it much resembles the tautog but is found in deeper waters and has a very different profile.

Similar Species: The Gulf sea bass or tally-wag, *Centropristes ocyurus,* looks like a small black sea bass, reaching a length of only about a foot. It is a deep-water form found in the Gulf of Mexico.

JEWFISHES: *Stereolepis, Promicrops, Garrupa*

These three largest of the basses are considered as a group although they are quite distinct from each other in appearance. They are separated from the groupers by size chiefly. The habits of all three are rather similar. All are somewhat clumsy-looking, extremely heavy, and rather sluggish. Nevertheless, they are voracious, very powerful, and swift in short spurts as the large fins would indicate. The jewfishes keep pretty much to the bottom, lurking in holes in shallow to moderately deep water. Not much is known of their habits. Jewfishes of large size are wary yet pugnacious fishes. Even small spotted jewfishes are known to snap if touched on the nose, but they will not attack if left unmolested. They learn very quickly that men with spears are up to no good and will avoid them very efficiently. These fishes school when young and are not often seen when small. Jewfishes are found in all tropical seas. The three North American species are as follows:

SPOTTED JEWFISH: *Promicrops itiara*

Size: Up to 8 feet.

Weight: Averages 20 to 100 pounds. Up to 700 pounds.

Distribution: West Indies to Florida. Gulf of California to Panama.

Identification: The body, head, and fins are a drab brown with many small dark spots. The ground color is often broken up by blotches and is somewhat variable. The tail fin is short and rounded and the spiny dorsal fin is long and low and not separated from the soft dorsal by a notch.

Similar Species: The huge *Promicrops lanceolata* of the South Pacific reaches a length of 10 to 12 feet and is the largest of the basses.

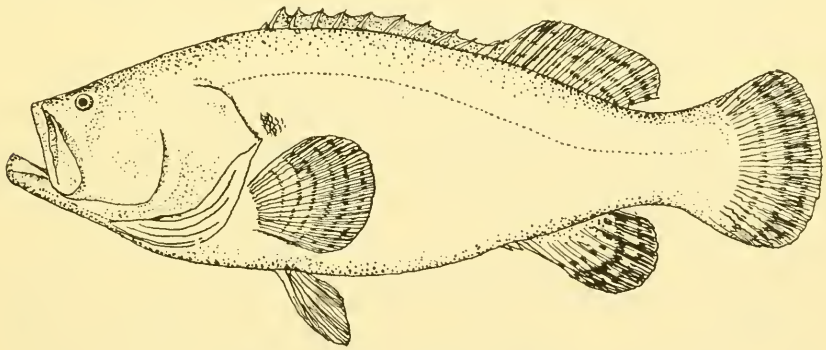


Fig. 123. Spotted jewfish.

BLACK JEWFISH (BLACK GROUPER): *Garrupa nigrita*

Size: Up to 6 feet.

Weight: Up to 500 pounds.

Distribution: South Carolina to Brazil. Eastward to the Mediterranean.

Identification: The dorsal fins are like those of *Epinephelus* species (see the following pages on groupers) but are anteriorly high. The head is huge, and the color is a uniform brown to blue-black.

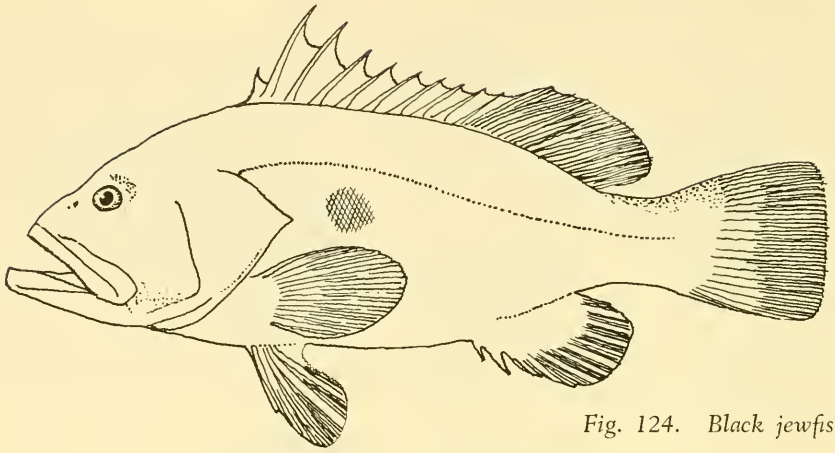


Fig. 124. Black jewfish.

CALIFORNIA JEWFISH: *Stereolepis gigas*

Size: Up to 7 feet.
Weight: Averages about 200 pounds. Up to 800 pounds.
Distribution: Farallone Islands to southern California.
Identification: The spiny dorsal fin is long and low and is separated from the soft dorsal by a notch, which separates this fish from the otherwise very similar spotted jewfish. Adults are a uniform greenish black to gray or brown. The young are blotched and have light edges to the dorsal, anal, and tail fins. This is one of the many species which undergoes great changes in shape and coloration during growth (Walford, 1937).

GROUPERS: *Mycteroperca, Epinephelus* and allied genera

There are many very confusing species of these fishes which are hard to identify. Ichthyologists separate the species by counting gill rakers, scales, and fin rays. Field identification of groupers is a study that has yet to be made in detail. It is complicated by the fact that there are many species which have very similar coloring. In addition, most of these have no one characteristic coloration but go through a series of complex color phases, which may in some cases adapt to environmental colors but often do not. Some of these color changes are probably due to the excitement of capture or other disturbances. Red becomes a dominant color in deep water in many species. All groupers have similar habits and are typical of rocky or coral areas in warm, mostly tropical seas, staying near the bottom usually, lying up in coral and in the holes of rocks or reefs. Their habits are similar to those of jewfishes, but their smaller size leads to greater activity. The great curiosity of basses has been noted, and it is probable that groupers surpass all other basses in this respect. It is virtually useless trying to get close to groupers that have repeatedly experienced the spear fisherman, but they are easy to approach if they have been unmolested or have been chummed. In relatively unfished areas in the Bahamas, the authors have frequently had groupers rise out of the reefs to greet them. Like jewfishes, they are not schooling, but will group together to feed or to spawn.

The largest North American groupers reach 4 feet and 60 to 100 pounds.

Spawning is in shallow water in spring or early summer. The young school. The dominant species are given below. (For the many less common species, reference will have to be made to the Bibliography.) We will consider the groupers as belonging to three groups below.

Genus *Mycteroperca.* The members of this huge and confusing genus have a rather broad, high forehead, a short upper jaw like a bulldog, and a long anal fin of eleven to twelve soft rays. The tail fin is usually square or rounded.

BLACK GROUPER (ROCKFISH, BONACI ARARA): *Mycteroperca bonaci–Color Plate 4*

Size: Up to 4 feet.

Weight: Common at 20 pounds. Up to 100 pounds.

Distribution: West Indies to Florida Keys. Straggles to Cape Cod.

Identification: Variable color. Usually a gray-olive, or blue-black ground color with large, dark quadrate blotches. The vertical fins often have a black border surmounted by a narrow light line. The pectoral fins are never tipped with yellow.

Similar Species: The gag, *Mycteroperca microlepis,* reaches 3 feet and 50 pounds and is very common in Florida from Pensacola around the peninsula northward to North Carolina. It is not found in the West Indies. It is a greenish, palely colored fish and has only indistinct blotches. The fins are dark olive to bluish with blue-black borders edged with white, as is common with several groupers. The scales are very small.

The scamp (salmon rockfish), *Mycteroperca falcata,* reaches 2 feet and 12 pounds or more. There are two distinct forms, a West Indian and a southern Florida one. The coloration of the scamp in the West Indies is brownish to grayish, faintly covered with small dark spots. The southern Florida scamp is a pale but pretty pink to purple-gray, spotted with smaller spots above and larger, obscure blotches on the sides. The fins of both are tipped with a darker gray, sometimes with whitish borders.

The broom-tailed grouper, *Mycteroperca xenarcha,* ranges from Mexico to Peru and reaches 60 pounds or more. It is dark gray to brown or green and blotched, and the tail fin rays are extended beyond the fin webbing so as to give a ragged look to this fin.

YELLOW-FIN GROUPER (RED ROCKFISH, BONACI CARDENAL): *Mycteroperca venenosa–Color Plate 4*

Size: Up to 3 feet.

Weight: Averages 10 to 15 pounds. Up to 35 pounds.

Distribution: West Indies to Florida. North rarely to Cape Hatteras.

Identification: The spiny dorsal and the pectoral fins are tipped with yellow. The ground color is light gray to olive or red and is covered with dark, oblong blotches and small dark spots. The vertical fins have a black border. The flesh is reported to be poisonous at times.

Similar Species: The Gulf grouper (cabilla de astillero, baya), *Mycteroperca jordani,* is common in bays and protected waters of western Mexico, particularly around Mazatlán and Guaymas. It reaches 3 feet in length. The color is olivaceous, darker above, with obscure, darker, quadrate, diffuse blotches arranged in four vertical series. The side of the head has wavy black streaks.

The princess rockfish, *Mycteroperca interstitialis,* is a small and very beautiful grouper which reaches a length of a little over a foot. There are many color phases, but in all these there are large spots, and bright colors predominate as a ground color. The commissure is yellow to yellow-green.

The tiger rockfish, *Mycteroperca tigris,* also has yellow-tipped pectorals. Its pattern is a rather striking blotched one with light stripes crossing the dark body. It is West Indian and grows to 2 feet in length.

The golden grouper (sardinera, leopard grouper), *Mycteroperca pardalis,* is greenish to brownish with small brown spots or a brilliant orange-yellow (sometimes blotched with black). It reaches 2 to 3 feet and is found from the Gulf of California southward.

Genus *Epinephelus.* This is fully as confusing a genus as the last. It is characterized by a low, narrow forehead, which makes the head look relatively long and pointed, and a short anal fin of seven to eight soft rays. The overall size of some is rather small. The tail fin is most often rounded, never concave or forked (except in the red grouper).

NASSAU GROUPER (HAMLET, CHERNA CRIOLLA): *Epinephelus striatus—Color Plate 4 and Figure 12*

Size: Up to 3½ feet.

Weight: Averages 15 pounds. Up to 50 pounds.

Distribution: Florida to the West Indies and Brazil. Straggles to Cape Hatteras.

Identification: This is one of the most familiar and easily identified of groupers. There are several color phases, but there is typically a diagonal stripe through the eye, a strong vertically barred pattern, and a black spot over the caudal peduncle. The black spot over the peduncle is the only characteristic that is unchanged in all color phases. The tail fin is rounded or nearly straight. A series of black spots rings the eye.

Similar Species: The red hamlet (mutton hamlet), *Alphestes afer,* looks roughly like a deep-bodied Nassau grouper and has a yellowish-brown ground color with indistinct, dark, vertical, mottled bars. The head is spotted heavily with yellowish to orange-brown spots and the breast with pale blue spots. The fins are dusky. It grows to a little over a foot and is West Indian, being particularly common in Puerto Rico, where it is an important food fish.

RED GROUPER (CHERNA AMERICANA): *Epinephelus morio—Color Plate 4*

Size: Up to 3 feet.

Weight: Averages 10 pounds. Up to 40 pounds.

Distribution: The most common grouper in the West Indies and Florida. Reaches Virginia and Rio de Janeiro.

Identification: There are several confusing color phases, but this is the only member of the genus with a distinctly square to concave tail. The spiny dorsal is high in front, tapering behind. The pattern is blotched, and there is considerable pattern resemblance to the Nassau grouper, but the color is a warmer reddish brown and the blotches are not arranged in distinct vertical bars. A plain, unblotched color phase is generally assumed when the fish becomes active.

ROCK HIND (POLKA DOT): *Epinephelus adscensionis*—*Color Plate 4*

Size: Averages 16 inches. Up to 18 to 20 inches.

Weight: Averages 2 pounds.

Distribution: West Indies north to Florida, straggling to Cape Cod.

Identification: This is one of the profusely spotted species. Small red to orange-brown spots cover the whole body, and small white spots are on the fins. The ground color is olivaceous, greenish, or grayish. There are usually large pale spots scattered among the reddish ones. The fins and tail are frequently yellowish.

Similar Species: The red hind (cabrilla mora) *Epinephelus guttata* (*Color Plate 4*), is similar to the rock hind in having a profuse covering of reddish spots. The body is usually reddish and has no lighter supplementary spots, large or small. The soft dorsal, tail, and anal fins are strikingly edged with black. It is a very common West Indian species found north to South Carolina.

The speckled hind (john-paw), *Epinephelus drummond-hayi,* is a large fish, principally of the Gulf of Mexico and ranging north to South Carolina. White spots cover the entire body and most of the fins. The ground color is a rich reddish brown. This beautiful fish reaches a weight of 30 to 50 pounds.

The snowy grouper, *Epinephelus niveatus,* is a deep-bodied, especially large-headed species with a lower jaw that projects even more than is normal for groupers. It has a brown ground color with fairly large white spots, a little smaller than the pupil of its eye, arranged in four vertical and five horizontal rows. The rows are sometimes irregular.

The spotted cabrilla (cabrilla pinta), *Epinephelus analogus* is abundant from Baja California to Ecuador. It is very similar to the rock hind in color pattern but tends toward a reddish ground color. It reaches a weight of 15 to 20 pounds, the largest of the western cabrillas (*Epinephelus* species).

The flag cabrilla, *Epinephelus labriformis,* reaches 20 inches and ranges south of Cape San Lucas. It is gray to brown or green and is covered with white spots.

Genera *Cephalopholis* and *Petrometopon.* These two genera both contain few species. Both are small and rather active fishes for groupers, and both exhibit a wide variety of color change. They are separated from other groupers by technical characters and by the fact that they have nine rays in the spiny dorsal fin instead of the usual ten or eleven. The caudal fin of both is rounded, and the forehead is low.

CONEY: *Cephalopholis fulvus*—*Color Plate 4*

Size: Up to about 1 foot.

Distribution: Florida and the West Indies.

Identification: There are several color phases. The ground color may be green, yellow, cream, or red and either mottled or not. There is always a sprinkling of light blue spots over the whole body. The jaws are tipped with black, and there are two spots over the caudal peduncle.

Similar Species: The Gulf coney, *Cephalopholis acanthistius,* is a chunky,

uniformly red fish with very high, soft dorsal spines. The rose coney, *Cephalopholis popino,* is also red. Both species are found from the Gulf of California southward. They both reach about 2 feet in length. They are probably rather rare and should be looked for.

GRAYSBY: *Petrometopon cruentatus—Color Plate 4*

Size: Up to about 1 foot.

Distribution: West Indies to Florida.

Identification: The ground color varies from nearly white to a mottled brown but is usually brownish-red. The body is covered with small dark spots. There is sometimes one row of large black or white spots just below the dorsal fin. A conspicuous row of black dots is sometimes present below the soft dorsal fin.

Similar Species: The enjambre, *Petrometopon panamaensis,* is reported from Concepción Bay to Panama. It much resembles the graysby.

OTHER BASSES

SOUTHERN CREOLE FISH: *Paranthias furcifer*

Size: Up to 10 to 12 inches.

Distribution: Cape San Lucas to the Galápagos Islands. Cuba to Brazil.

Identification: This is a bright red to dark reddish-gray fish with several bright blue spots on the sides and a bright blue spot at the base of the pectoral fin. The tail is very noticeably concave, and the entire dorsal fin is low.

Habits: It is probably a carnivore found in rocky places like others of the family.

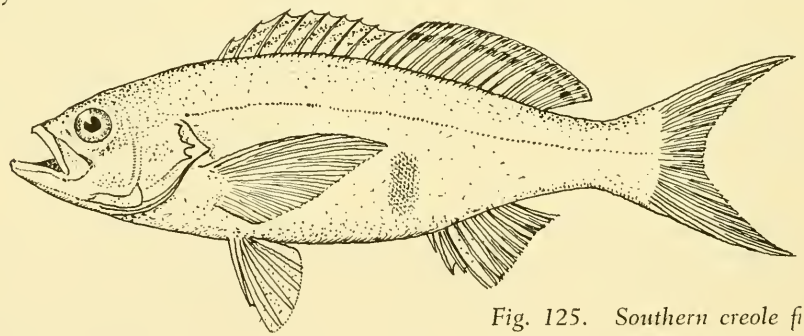


Fig. 125. Southern creole fish.

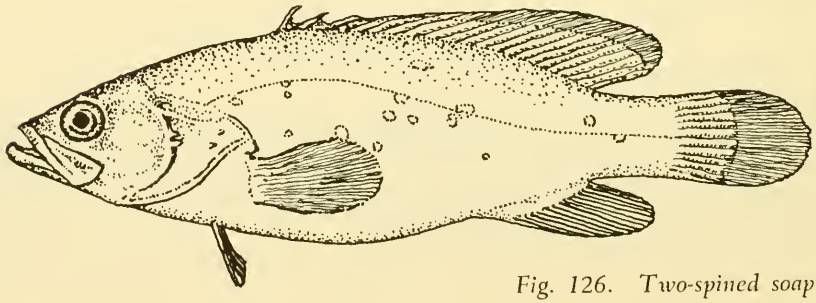


Fig. 126. Two-spined soapfish.

TWO-SPINED SOAPFISH: *Rypticus bistrispinus*

Size: Averages 8 inches. Up to 1 foot.

Distribution: West Indies, straggling to Cape Cod. Also western tropical Mexico.

Identification: The peculiar shape, with only two spines in the soft dorsal, identify it. The color is a dusky olive to dull purple.

Habits: The authors have seen these fishes around coral heads in shallow water, but they probably keep to moderately deep water much of the time. When handled, they secrete a mucus remarkably like soap suds.

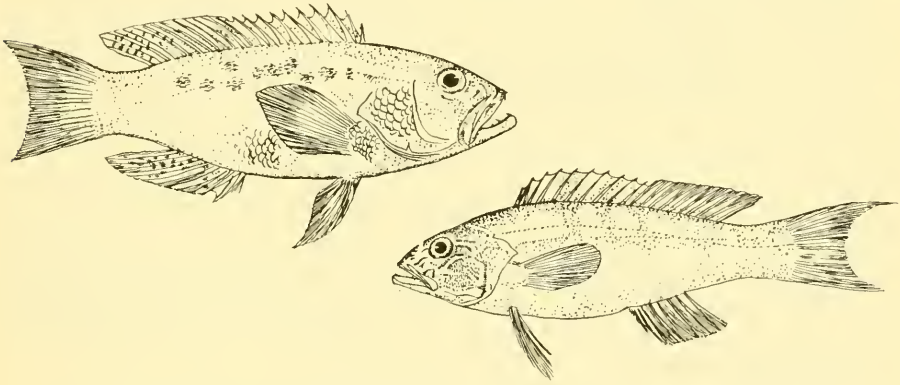


Fig. 127. Midget sea basses. Prionodes (*left*) *and* Diplectrum (*right*).

HARLEQUIN SERRANID: *Prionodes tigrinus–Figure 12*

Size: Rarely over 4 inches.

Distribution: West Indies.

Identification: The very low forehead, long snout, and distinctive barred pattern identify this fish. This species and those similar to it have forked or lunate caudal fins.

Habits: This little bass is one of a number of very small basses of tropical seas. Most keep to fairly deep water. Their movements are quick, flitting, and altogther birdlike as they dart about reefs in search of small invertebrates on which to feed. This species is one that keeps to shallow water.

Similar Species: Among the many midget basses is the sandfish, *Diplectrum formosum.* It reaches a length of almost a foot but is usually smaller, has a very spiny preoperculum, and is found along eastern shores from North Carolina to Texas. It is gray or tan with stripes on the body and head and has a large eye.

The phoebe or tattler, *Prionodes phoebe,* grows to 8 inches, has a prominent white bar on the side, is typical of deeper water, and is found in the West Indies.

The butler hamlet, *Hypoplecturus unicolor,* looks a great deal like a demoiselle, with its compressed deep body, but the head and mouth are large. The coloration is extremely variable. The colors are usually bright yellows, lavenders, greens, or

blues. There is usually a pattern of vertical bars. It rarely grows over half a foot but does occasionally reach a foot. It is found about rocky or coral areas in the West Indies.

Three species of serranos, genus *Prionodes,* and three species of squirrel fish, genus *Diplectrum,* are known on the West Coast from the Gulf of California southward.

BLUE AND GOLD FAIRY BASS: *Gramma hemichrysos—Color Plate* 3

Size: Up to 2 to 3 inches.

Distribution: West Indies to Florida and Bermuda.

Identification: The long ventrals and the extremely vivid coloration, the anterior half of the fish purple, the posterior half orange-gold, are unmistakable.

Habits: This is one of the most beautiful of all fishes. Its very striking color and lively flitting movements make it truly like a jewel. This fish was thought until recently to be a rather rare fish, but this is certainly not so. The reason it was so seldom seen by surface ichthyologists is simple. This fish lives habitually under dark ledges and holes in reef areas. The underwater swimmer finds it extremely common. It lives in an upside-down world, traveling belly up very close to the undersides of ledges as it gleans small bits of invertebrate food from these surfaces. Unlike the little fresh-water upside-down catfish, the fairy bass can travel normally right side up, but it seems to prefer its upside-down position. It is rarely seen alone. A few individuals, up to a dozen or so, form small social groups.

TRIPLETAILS: Family Lobotidae

There is but one genus of two to three species which are found in all warm seas.

TRIPLETAIL (FLASHER, CHOBIE, DUSKY PERCH): *Lobotes surinamensis*

Size: Up to 3 feet.

Weight: Averages 5 to 10 pounds. Up to 40 pounds or more.

Distribution: West Indies to Europe and Africa. Gulf of Mexico, Atlantic coast to the Carolinas, straggling to Cape Cod.

Identification: The "triple tail" of the soft dorsal, caudal, and anal fins is the best field mark. The head is small and short. The color varies from dark brown to greenish or light yellow-brown.

Habits: The young are often seen in sargasso weed. The adults school or are solitary in water about 50 feet deep around rocks, wrecks, pilings, or reefs. The habits are probably much like those of the groupers.

Similar Species: The West Coast tripletail, *Lobotes pacificus,* is found from Panama to the Indo-Pacific.

BIG-EYES OR CATALUFAS: Family Priacanthidae

There are several quite similar species of these beautiful red fishes distributed in all tropical seas around reefs. The eyes are huge and glassy, capable of reflecting a beam of light upward. The habits are like those of squirrel fishes in that these fishes are largely nocturnal and carnivorous and live singly in holes in reefs. They may be easily separated from squirrel fishes by the anal

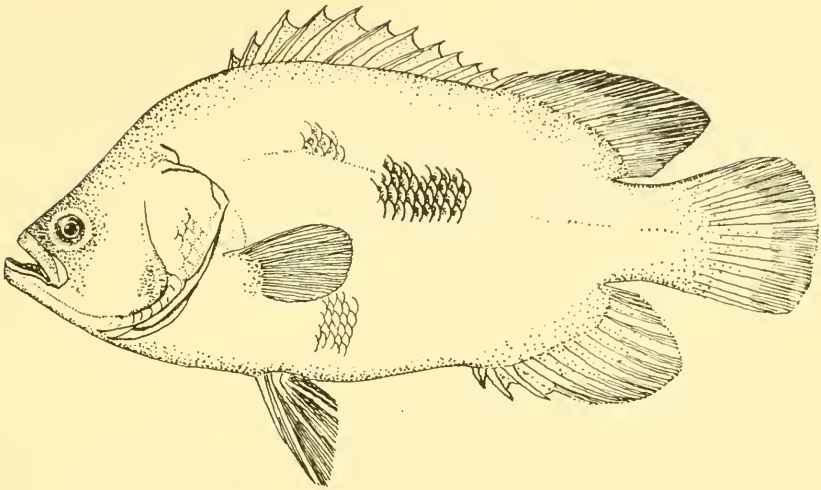


Fig. 128. Tripletail.

fin's shape and length and the bulldoglike, underslung lower jaw. Many big-eyes live in moderately deep water.

COMMON BIG-EYE (GLASS-EYE): *Priacanthus arenatus—Color Plate 4*

Size: Averages 8 inches. Up to over a foot.

Distribution: West Indies. The young straggle to Cape Cod.

Identification: The eye, the color, and the long anal fin identify it.

Habits: The authors have found this fish lurking deep in holes by day, only occasionally appearing in the open then. It becomes active by night. Little is known of its habits.

Similar Species: The deep big-eye, *Pseudopriacanthus altus,* is an almost round, shorter version of the common big-eye. It is West Indian and found north to the Carolinas.

SNAPPERS OR PARGOS: Family Lutianidae

Second only to the basses in abundance, diversity, and importance in the tropics are the snappers. There are 250 species of these fishes in the world, many of them identified by very technical characters such as tooth pattern. Snappers are carnivorous, voracious fishes which feed primarily on other fishes and crustaceans at night. They contrast with groupers in that they are schooling and rather wary. Under water they like to keep quite a few feet of water between themselves and the swimmer. It is said of some species that if one is taken from a school, the rest will become very wary and stop feeding. The head is more pointed, the mouth smaller, and the body less massive than those of the groupers. The pectoral fins are pointed rather than rounded as in basses. Though some of them reach a very large size of 80 pounds or more, the usual maximum size is 2 feet and 15 to 20 pounds. In this family and the following families of perchlike fishes, the maxillary bone slips into a slot beneath the eye, making the rear part of the upper lip look more slender than in the preceding perchlike

families. The dominant color is a barred dark green on the body with yellow or red fins, but almost all species show several color phases. There is a tendency for many species to become red in deep water. In almost all of them some teeth in the front of both jaws are enlarged and caninelike. Some large snappers have been observed to stand with their mouths wide open, allowing butterfly fishes to probe deep in their throats for parasites.

Most snappers are delicious as food, but some are variously reported to cause a fish poisoning called "ciguatera."

GRAY SNAPPER (MANGROVE SNAPPER, PARGO PRIETO): *Lutianus griseus—Color Plate 5*

Size: Averages 1½ feet. Up to 3 feet rarely.

Weight: Averages 2 to 3 pounds. Rarely up to 18 pounds.

Distribution: West Indies. North to New Jersey.

Identification: The body is usually dark greenish, becoming reddish in deep water. The dorsal and caudal fins are dark gray or blackish. The anal and paired fins are flesh-colored or rose. The greenish, shallow-water forms are faintly barred as are many snappers.

Habits: This is the most common of the snappers. It lurks in mangrove groves, coral areas, and harbors, and strays to deeper water. It is catholic in tastes, eating fishes, tree crabs from the mangroves, and even a certain amount of refuse. LaMonte (1952) reports that it often schools with the yellowtail snapper.

Similar Species: The dog snapper or jocu, *Lutianus jocu,* is found from the West Indies to Florida and straggles to Cape Cod. It reaches a weight of 20 pounds. The color is much like that of the gray snapper, but the sides are distinctly reddish or coppery, and the dorsal and caudal fins are reddish, the paired fins yellowish. There is also a large whitish area below the eye. The dog snapper may, in some places, be poisonous as food.

The muttonfish (pargo criollo), *Lutianus analis,* reaches over 2½ feet and 25 pounds. It is common from the West Indies and Florida and straggles to Cape Cod. It strongly resembles the gray snapper, but all the fins are reddish, and there is a prominent blue bar under the eye from the nostril to the rear end of the gill cover. There are rows of pale blue spots extending obliquely up and back from the lateral line. The iris of the eye is fiery red.

The pargo prieto or dog snapper, *Lutianus novemfasciatus,* reaches 80 pounds or more and is common from Cape San Lucas south to Panama. It is like a gray snapper in body color when young, frequently having a slate tinge above, with the lower parts white. Older specimens are a uniform reddish-brown color. The inside of the mouth is a reddish yellow and bears very large, caninelike teeth.

SCHOOLMASTER (PARGO AMARILLO): *Lutianus apodus—Color Plate 5*

Size: Averages 18 inches. Reaches 2 feet.

Weight: Averages 2 to 3 pounds. Reaches 8 pounds.

Distribution: West Indies north to Florida. Straggles to Cape Cod when young.

Identification: The ground color varies from a barred greenish or grayish with

orange tints to a plain, pale slate color. This is the only snapper whose fins are all yellowish. The young have a blue bar below the eye from the nostril to the rear edge of the operculum. There is a reddish-brown, barred phase in which the fins are also yellowish.

Habits: This is a very abundant and pretty fish. It eats fishes and crustaceans and is commonly found lurking in inshore coral heads in small schools. Like other snappers, it is wary and nervous in the swimmer's presence.

Similar Species: The pargo amarillo or yellowtail snapper, *Lutianus argentiventris,* is a West Coast species found from Mazatlán southward. It resembles the schoolmaster but is rosy on the front part of the body and yellow to the rear. It reaches 2 feet.

The spot snapper (lane snapper), *Lutianus synagris* is very common from Tampa southward through the West Indies. Identification is made easy by the presence of a large dark spot, larger than the eye, below the juncture of the spiny and soft dorsal fins on the back. Like the schoolmaster, it is a colorful species. It has yellowish stripes running horizontally on its sides. It reaches only a foot in length.

RED SNAPPER (PARGO GUACHINANGO, PARGO COLORADO): *Lutianus aya*—*Color Plate 5*

Size: Averages 20 inches. Up to 3 feet.

Weight: Averages 5 pounds. Up to 20 pounds.

Distribution: Gulf of Mexico and the West Indies. A very similar fish, common on the Florida East Coast north to South Carolina and rarely to Cape Cod, has been named as a separate species by some.

Identification: The color is a pretty rose-red. The anal and soft dorsal fins are angular, not round, and this should separate it from other snappers which have reddish deep-water forms.

Habits: This is the most sought after of the snappers for food. It normally lives in fairly deep water of over 100 feet and feeds on fishes and crustaceans. Apparently it schools quite densely off coral banks called "snapper banks."

Similar Species: Many species of snappers tend to become reddish when they get large or live in deep water. The Colorado snapper or pargo colorado, *Lutianus colorado,* found in the Gulf of California to Panama, has the angular anal and soft dorsal fins and the reddish color of the red snapper. The silk snapper, *Lutianus vivanus,* is West Indian and weighs up to 40 pounds. It is red of body, but the tail fin is yellow.

YELLOWTAIL SNAPPER (RABIRUBIA): *Ocyurus chrysurus*—*Color Plate 5*

Size: Up to 2 feet.

Weight: Averages 1 pound. Up to 6 pounds.

Distribution: Southern Florida through the West Indies to Brazil.

Identification: A very large, forked, yellow tail and a broad yellow stripe from the eye to the tail are distinctive. Above this stripe the pattern is a spotted yellow on a blue ground color, and below the stripe the pattern is one of thin yellow stripes. This coloration is variable, but not as much as in other species of snappers. The anal fin is relatively long.

Habits: Contrary to most snappers, this species is found singly as often as it

is found in schools. It is, perhaps, not as wary as other snappers, but it is very speedy and active; it can be a frustrating fish to observe and photograph. It feeds on fishes and crustaceans and may also take certain amounts of plant matter. It swims over a wide variety of bottoms, from mud to sand or grass, but it is usually found near reefs. It seems to prefer gorgonian beds. The yellowtail is rather unique among snappers since it is quite commonly seen swimming four to six feet from the bottom in open water of up to twenty-five feet in depth rather than lurking under ledges or in dark places.

Similar Species: The Pacific rabirubia, *Rabirubia inermis,* has the general shape, the forked tail, and the long anal fin of the yellowtail, but it is rose-colored, and there are oblique rows of spots above the lateral line and horizontal rows below. It reaches 12 inches and is found from Cape San Lucas to Panama.

STRIPED PARGO (PARGO RAISERO): *Hoplopagrus guntheri*

Size: Reaches 2 feet.

Distribution: From Guaymas and Mazatlán southward to Panama.

Identification: The heavy body and the coloration are good identifying characters. The ground color is dark brown to greenish gold on the upper side, coppery to maroon on the lower side, and there are oblique, downward-running bars, six in number, present on the back. The bars may be lost in older individuals.

Habits: This is a snapper of rocky shores. Not much is known of its habits, and it is not very abundant.

GRUNTS OR RONCOS: Family Haemulidae

These extremely plentiful, tropical fishes are very closely related to the snappers, but they are usually much smaller, less wary, and do not have enlarged teeth in the front of the mouth. Like snappers, the maxillary bone slips

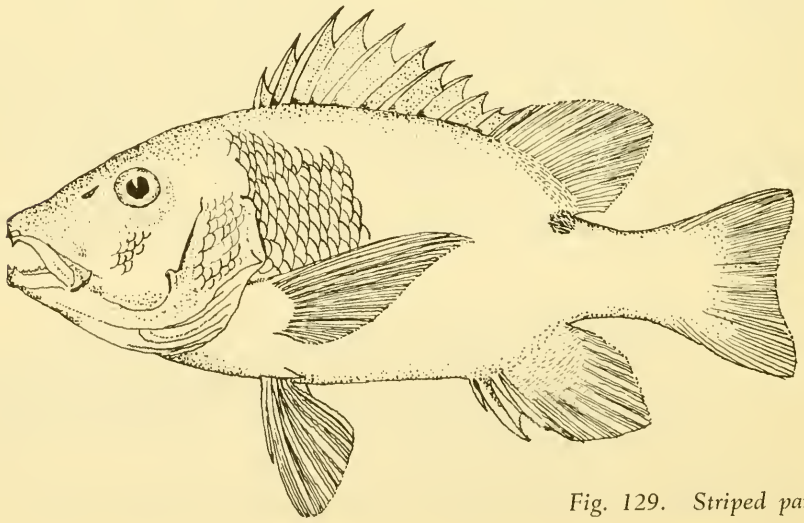


Fig. 129. Striped pargo.

into a slot below the eye. Yellow is a predominant color, and there is often a red lining inside the mouth. Many species show light and dark color phases which adapt to the environment, a light phase being common when the fish swims in open water. Some of them are deep-bodied. They are usually schooling in habits, especially in the breeding season in summer. They are carnivorous, mainly on fishes and invertebrates, feeding principally at night. The Spanish name "ronco" comes from *roncar,* "to snore," a description of the sound these fishes are able to make with the pharyngeal teeth and complex swim bladder.

Several species of the genus *Haemulon* have the peculiar habit of rushing at each other open-mouthed and "kissing" (*fig. 131*). The authors have seen several species, notably the blue-striped grunt, do this repeatedly in late summer, the breeding season. The reason for this habit is not known. It may be a sexual display of some sort since the same pair of fishes has been observed by the authors to kiss repeatedly, even driving intruders away. Another theory is that this is an aggressive display, leading to the establishment of hierarchies, but the most popular idea is that this is a territorial display of some sort.

Grunts lay pelagic eggs. They are cosmopolitan in warm seas, but the large genus, *Haemulon,* is solely American. There are over fifty species in North and Central America.

CAESAR (TOM TATE, RED-MOUTH GRUNT): *Bathystoma rimator*

Size: Up to 10 inches, but normally 5 inches.

Distribution: From Cape Hatteras southward through the West Indies.

Identification: Members of this genus are elongate grunts with large, very red mouths. The color of this species is silvery white to gray, bluish above.

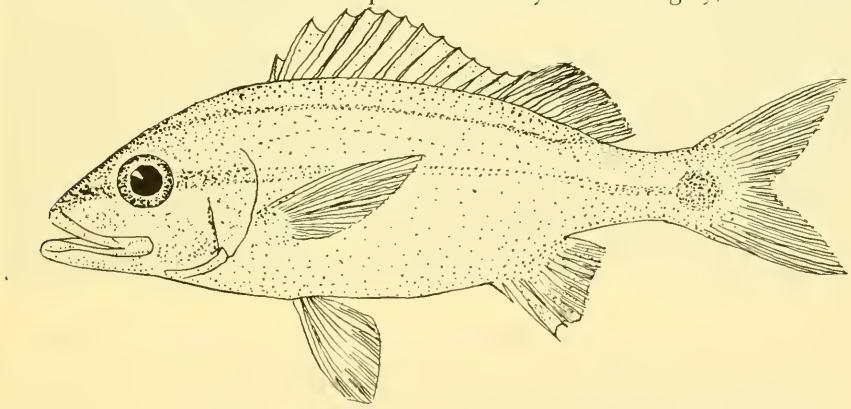


Fig. 130. Caesar.

There are rows of horizontal yellow spots below the lateral line and oblique rows of yellow spots above. There are two prominent yellow stripes, one from the eye to the caudal fin and another above that from the head to the end of the soft dorsal. The fins are not colored. Young fish have horizontal dark lines and a caudal spot.

Habits: This is a swarming, inquisitive little fish common around docks and shores. It is omnivorous and very active as it noses about for food.

Similar Species: The yellow tom tate (white grunt), *Bathystoma aureolineatum,* grows to only 8 inches and is common from the West Indies to Bermuda. It is grayish with several yellow longitudinal stripes, the one through the eye being the largest. There is sometimes a dark spot at the base of the caudal fin.

The common tom tate (white grunt), *Bathystoma striatum,* is another West Indian species. It is very similar to the yellow tom tate, its chief difference being its smaller mouth, the maxillary not quite reaching to the middle of the eye. Both of these species are slimmer of body than the caesar.

The burros, genera *Brachydeuterus* and *Pomadasis,* are small grunts of the Gulf of California south and the West Indies. They are named after the burrowlike, snoring noise that they can make. There are several species which are hard to tell apart.

YELLOW GRUNT (FRENCH GRUNT): *Haemulon flavolineatum—Color Plate 5 and Figure 131*

Size: Averages 6 to 8 inches. Up to 1 foot.

Distribution: West Indies to the Florida Keys and Bermuda.

Identification: The coloration consists of very striking longitudinal striping of alternating blue-gray and yellow. The fins are all yellow. The eyes are large and glassy, and the inside of the mouth is a brilliant red.

Habits: This is one of the most common of West Indian fishes. It is usually seen swimming around inshore reefs and wrecks and sandy shores. This species and the species similar to it are the ones most frequently observed to "kiss." Yellow grunts gather in large schools in the late summer breeding season. At other times they travel in smaller schools or even singly.

Similar Species: The white or common grunt, *Haemulon plumieri,* is the most common grunt and one of the most common fishes from Cape Hatteras to Florida; it is also common throughout the Caribbean. It averages under a foot and reaches 18 inches. This fish is common almost everywhere, especially on sandy shores. It is light bluish and has yellow and blue lines like the yellow grunt, but on the head only.

The blue-striped grunt (yellow grunt, boar grunt, ronco amarillo), *Haemulon sciurus,* strongly resembles the yellow grunt, but the vertical fins are dark-bordered, and the size is larger, averaging 8 to 12 inches and reaching 18 inches (*fig. 131*).

MARGATE FISH (SAILOR'S CHOICE, BREAM): *Haemulon album—Color Plate 5*

Size: Up to over 2 feet.

Weight: Averages 1 to 2 pounds. Up to 10 pounds or more.

Distribution: West Indies and the Florida Keys.

Identification: The color is pearl-gray to olivaceous, faintly bluish below with olivaceous fins and a dark stripe running from the nose, through the eye, and back to the tail. There are two more curved stripes running above this one. Color phases occur in which the stripes are obscure.

Habits: This is an offshore, reef species coming to shallow water to feed on various invertebrates. The name "margate" is derived from the English seaport of the same name, which was the original home of some of the inhabitants of the West Indies. The spawning time is early summer, at which time this fish schools.

Fig. 131. Top. Yellow grunt, Haemulon flavolineatum, *school around reefs and wrecks like the propeller shaft of this World War I tanker. Bottom. Why the blue-striped grunt,* Haemulon sciurus, *"kiss" is unknown, but the cause may be sexual, territorial or aggressive and leading to the establishment of hierarchies.*

Similar Species: The sailor's choice (ronco), *Haemulon parra,* is a gray fish with dark fins. Small black spots above the lateral line form oblique, backward-running streaks. It reaches a foot in length, swimming alone or in small groups among the reefs, mangroves, and shallow waters of the Florida Keys and the West Indies. The mojarra prieta, *Haemulon scudderi,* is the West Coast representative of the sailor's choice, being of the same small size and having a similar pattern. It is found from the Gulf of California to Panama.

PORKFISH: *Anistotremus virginicus—Color Plate 5*

Size: Averages 6 inches. Up to 16 inches.
Weight: Up to 2 pounds.
Distribution: Florida to the West Indies.
Identification: The two black bars on the head and fore-body and the yellow-

and-blue horizontal body striping are unique. The forehead is very steep, the mouth small, and the body deep in members of this genus. The young are yellow on the head and back, fading to gray below; the sides bear two dark longitudinal stripes, the lower one extending from the eye to the tail fin.

Habits: This is a very common and pretty little fish. It is typical of shallow, inshore waters and feeds at night on invertebrates. It schools densely in shoal waters in the summer spawning season. Longley and Hildebrand (1941) report that the young peck at the surfaces of large fishes such as barracudas, jacks, and snappers, presumably to remove ectoparasites.

Similar Species: The pompon or black margate, *Anistotremis surinamensis*, is the largest of the grunts, reaching 3 feet and 20 pounds but averaging only 1 to 4 pounds. This is a silver-gray fish with dark gray vertical fins and most often with a dark gray saddle on the belly and sides just behind the pectoral fins. As in the porkfish, the forehead is high. It swims in rather deep water around reefs and channels and ranges from Florida to the West Indies.

The sargo, *Anistrotremus davidsoni*, is a dark-spotted, silvery fish with a prominent black bar running from the base of the spiny dorsal to behind the pectoral fin. The fins are yellow. It is a small fish of under a foot found in many types of habitats from the shallow waters of Point Conception to Baja California.

PIGFISH (SAILOR'S CHOICE): *Orthopristis chrysopterus—Color Plate 5*

Size: Averages 6 inches. Up to 15 inches.

Weight: Up to 2 pounds.

Distribution: Gulf of Mexico, Florida, north to the Carolinas and Virginia. Straggles to Massachusetts.

Identification: The anal fin is long for a grunt and reflects the soft dorsal in size, shape, and its edging of black. The head is long and pointed. The color pattern of orange-brown spots extending in oblique rows up and back from the lateral line on a blue ground color, and spots of the same color in horizontal rows below the lateral line, is distinctive.

Habits: This is a very common fish over sand, rock, or grassy bottoms of shallow coastal waters. Its food consists of small invertebrates largely. It is an excellent pan fish.

Similar Species: There are several confusing members of this genus on the West Coast from the Gulf of California southward and in the West Indies. All have the long head and long anal fin.

PORGIES: Family Sparidae

This group is closely related to grunts, but carries further the tendency of grunts to be deep at the shoulder and compressed of body. This gives most of them a steep profile with the eye placed high over and in back of the small mouth. The anal fin tends to be longer than in grunts and reflects the shape of the soft dorsal fin. There are over one hundred species of porgies found the world over, chiefly in tropical seas. Most of these are of moderate to rather small size, and most school inshore or offshore over hard or soft bottoms. Several species are common about reefs, but many are more typical of sandy or grassy shores; several reach into temperate waters, where grunts are not commonly found. Larger ones are wary in the presence of the swimmer. The teeth are project-

ANSCOCHROME-BAHAMAS

The red parrotfish, a common reef-grazer which, like other parrotfishes, can crunch coral with its hard beak, shows its red fins ten feet underwater.

Green parrotfishes, with blue tang and an indigo parrotfish, do not school, but are usually seen grouped together feeding.

ANSCOCHROME-BAHAMAS

ANSCOCHROME-BAHAMAS

One of the smallest and most common of parrotfishes, unattractively called the mud-belly, provides a decoration for stone coral.

The four-eyed butterflyfish masks its real eye with a stripe and has a false eye-spot near its tail to confuse predators. It is usually seen travelling in pairs.

ANSCOCHROME-BAHAMAS

ing and like incisors in the front and like molars in the rear. The possession of more than one kind of tooth in fish is rare. This condition is called "heterodont." Porgies are practically omnivorous. They eat small fishes, invertebrates, shellfish, and some plant matter. The predominant ground color is silver, and there are usually rather dull markings of black and flecks of brighter colors. Most species show plain, light color phases over sand bottoms and darker, barred phases over reefs, grass, or dark bottoms. Many are important food fishes. Two of the most famous of these are the European dentex and that symbol of good luck and well-being, Japan's red tai.

NORTHERN PORGY (SCUP): *Stenotomus chrysops*

Size: Averages 8 to 10 inches. Up to 18 inches.
Weight: Averages 1 to 1½ pounds. Up to 4 pounds.
Distribution: Cape Hatteras to New England, moving north in spring and summer.
Identification: The body is about the same depth along the whole length of the dorsal, giving it a different shape from that of the genus *Calamus*. The color is a dull silver, becoming olivaceous above. There are bright silvery blotches on the sides, and the fins are dusky.
Habits: This is a schooling, migratory fish which comes north and inshore during the warmer months. It feeds on a wide variety of animals, chiefly molluscs, worms and crustaceans. It is most common over sandy or hard gravel bottoms.
Similar Species: The southern porgy, *Stenotomus aculeatus*, replaces the northern porgy south of Cape Hatteras and ranges to Texas. It is very similar to the northern porgy, but has a less steep profile.

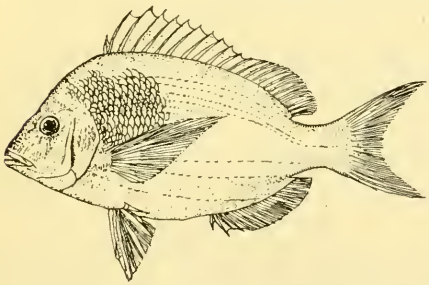


Fig. 132. Northern porgy.

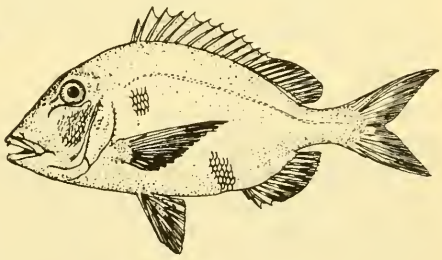


Fig. 133. Jolt-head porgy.

JOLT-HEAD PORGY (BLUE-BONE PORGY, GRASS PORGY): *Calamus bajonado*

Size: The largest of the genus, reaching 2 feet or more.
Weight: Reaching 10 pounds or more.
Distribution: West Indies and Bermuda to the Florida Keys.

Identification: All members of this genus have the peculiar, high, rounded forehead, the high-placed, large eye, and the body depth greatest through the shoulder that make a characteristic silhouette. The teeth are also odd, being like canines rather than like incisors in the front of the mouth. This species is usually of dull, brassy, plain coloration. There is a slender blue streak below the eye. When feeding over a grassy bottom a banded phase may be displayed and when over sand, a clear gray phase.

Habits: This is a typical, omnivorous, schooling porgy and is the most common member of this typically American genus, all species of which are inshore inhabitants of the West Indies. The common name of this fish is reported by Breder (1940) to be derived from the habit this fish has of jolting molluscs loose from rocks with its jaws.

Similar Species: The following species all have the silhouette of the jolt-head and are best separated by color pattern. All are found in the West Indies, ranging north to the Florida Keys.

The saucer-eye porgy, *Calamus calamus*, reaches a length of about 1½ feet, but is usually much smaller. The color is silvery with bluish reflections and a yellowish wash, which is strongest anterio-dorsally. Golden spots on each scale form indistinct longitudinal rows. There is usually a violet stripe below the eye. A banded phase may occasionally be encountered over a dark bottom.

The little-head porgy, *Calamus proridens*, reaches 12 inches, is of a brighter silver than other *Calamus* species, and has violet longitudinal rows of spots on the sides and pale orange spots below.

The grass porgy, *Calamus arctifrons*, lives chiefly in the grassy, shallow water of the Gulf of Mexico. It has conspicuous dark bars and blotches, over a dull silver ground color, which serve to camouflage it. It is the smallest of the porgies, reaching only a foot.

SHEEPSHEAD: *Archosargus probatocephalus*

Size: Up to 3 feet.

Weight: Averages 1 to 4 pounds. Large at 5 to 15 pounds. Up to 30 pounds.

Distribution: Cape Cod to Texas. Overfishing has caused it to become scarce in much of its range.

Identification: This large, chunky fish is immediately distinguished by the wide, vertical, nearly black bars that cross its body. These fade in large individuals.

Habits: The sheepshead derives its name from its flat molar teeth, used to crush its food, which consists mostly of molluscs and crustaceans. The fishes group or school inshore over hard, rocky, or even reef bottoms. They will stray into brackish water or even into the fresh water of rivers. They are most common inshore in the summer. This is especially true north of Cape Hatteras, where they are not present at all in winter.

Similar Species: The brim (salema), *Archosargus unimaculatus*, is a southern Florida and West Indian species. It reaches the length of only a foot but has the same shape as the sheepshead. The coloration is pretty and distinctive. There are only faint dark crossbars. The back is blue, with wavy streaks of brilliant gold. There is a black spot above the pectoral fin base, and the underside is silvery.

The pinfish (sailor's choice), *Lagodon rhomboides*, reaches only 10 inches. It ranges from Cape Cod to Cuba and Texas, being common only south of Delaware. The vertical barring is faint or absent, and there are gold stripes, fainter than those of the brim, running on the back and sides from gill cover to the tail fin, which is yellowish. There is also a dark spot above the pectoral fin as in the brim.

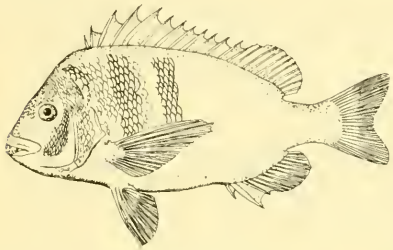


Fig. 134. Sheepshead.

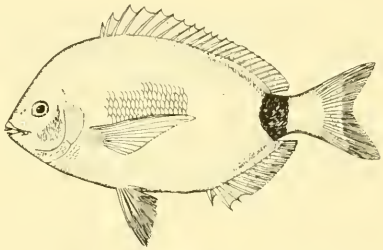


Fig. 135. Bream.

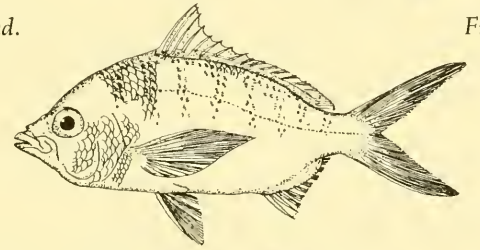


Fig. 136. Gray mojarra.

BREAM (SILVER PORGY, SARGO, PINFISH, SPOT): *Diplodus holbrooki*

Size: Averages 8 to 12 inches. Up to 20 inches.

Distribution: From Cape Hatteras south to the Gulf of Mexico.

Identification: The black spot on the caudal peduncle is distinctive. There may be faint dark crossbars on this otherwise plain, silver fish.

Habits: This fish swims in small groups about shallow reefs or in rocky waters. It seems to prefer to swim in the shallow, sandy areas near or between rocky places or coral heads, and it often schools with snappers, grunts, porkfish and smaller parrot fish. It is omnivorous on various animal and plant foods.

Similar Species: This species is replaced by the silver bream, *Diplodus argenteus*, in the West Indies.

MOJARRAS: Family Gerridae

These are small, intensely silver fishes predominant in American waters but found in all tropical and subtropical seas. The mouth is extremely protrusible, and the maxillary bone folds into a noticeable slot below the eye and on the snout. This gives the lips a peculiar pursed look. The spiny dorsal fin is high anteriorly, sloping behind. There are several species, but all are quite similar to one another and are principally inhabitants of sandy shores.

GRAY MOJARRA (SHAD, MOJARRA BLANCA): *Gerres cinereus*

Size: Averages 8 inches. Up to a little over a foot.

Distribution: The West Indies north to Florida. Tropical west coast of Mexico.

Identification: The usual intense silvery color of mojarras is crossed by dusky bands, which are more evident in young fish.

Habits: This little fish swims actively in shallow water, usually over a sandy bottom. It is omnivorous and schooling.

Similar Species: The mojarra, *Eucinostomus californiensis*, reaches 8 inches and is common in bays from Cape San Lucas to Panama. The common mojarra, *Eucinostomus gula*, reaches 6 inches and ranges from Cape Hatteras to Brazil. Both of these lack the crossbanding of the gray mojarra, though indistinct blotches may be present.

RUDDERFISHES: Family Kyphosidae

Rudderfishes received their name from their habit of following in the wake of boats. They have incisor teeth in the front of the small mouth but have no molars. This befits their algae-eating habits. They also eat some small invertebrates. The body is spindle-shaped, and the dorsal and anal fins are long and low. There are not many species, but their distribution is world-wide, chiefly in the tropics. Small pods or large schools of them mill about rocks grazing on algae, depending upon alertness and speed for protection.

BERMUDA CHUB (CHOPA): *Kyphosus sectatrix—Color Plate 8*

Size: Averages 1 foot or more.

Weight: Up to 20 pounds.

Distribution: From the West Indies north to Florida. Straggles to Cape Cod.

Identification: The ground color is slaty. There are thin, dull yellow, horizontal stripes, and there is a color phase which has large light spots on the back and sides. The color becomes darker when the fish swims under coral ledges or in holes.

Habits: This is an active and curious fish. It swims chiefly in reef waters that have access to the open sea and will follow ships long distances out to sea, probably to feed on garbage. Its flesh is very firm and delicious to eat.

Similar Species: There are several similarly shaped species ranging north to the Canary Islands and on the West Coast from the Gulf of California southward. One of these, the California halfmoon, *Medialuna californiensis*, is found from southern California to Cedros Island. It has a steely ground color with oblique rows of spots and blackish fins.

OPALEYE (GREENFISH): *Girella nigricans—Color Plate 8*

Size: Averages 10 inches. Up to 15 inches.

Distribution: San Francisco to Cape San Lucas.

Identification: The color is uniform light to dark green. There is a prominent yellowish spot below the spiny dorsal fin on the back.

Habits: This is an active little inshore fish, speedy and alert, common in shallow, rocky waters where it browses on seaweed.

CROAKERS: Family Sciaenidae

This is the last of the complex perchlike families, and it is a large one, containing 150 species. Though these species are extremely variable in form, the habitat variation is not extensive. Croakers are conspicuous in warm temperate

or tropical waters, never far from shore and rarely over any but sandy bottoms. Most school or are found in small groups. Most of them have the spiny and soft dorsal fins separated by a deep notch. The anal fin is usually much shorter than the soft dorsal fin. The lateral line extends all the way to the end of the tail fin. There is no one dominant ground color in the family, but very few species have bright coloration.

Many of the species reach a very large size and are very important commercially (especially the various sea "trout"). Almost all species are able to make a noise, variously described as drumming, croaking, snoring, or grunting, by using their complex swim bladders as resonating chambers. Strangely enough, members of one genus, *Menticirrhus*, lacks the swim bladder completely. All croakers are carnivorous. So far as is known, all lay pelagic, floating eggs, which hatch in a very short time.

SILVER PERCH: *Bairdella chrysura*

Size: Up to 1 foot. Usually smaller.

Distribution: New York to Texas.

Identification: The color is a dull silver with greenish above. The scales on the back and sides each have a dark spot.

Habits: This is a common shore fish often confused with the white perch. It schools heavily and feeds on all manner of animals, mostly invertebrates. During the colder months it migrates offshore.

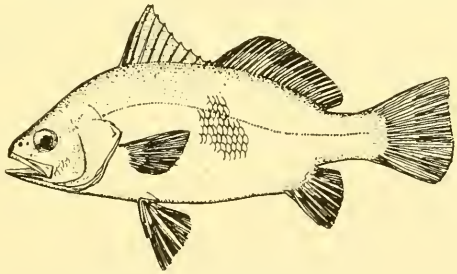


Fig. 137. Silver perch.

SEA TROUTS: Genus *Cynoscion*

There are several species of these very important and large fishes all of which resemble each other strongly in habits. They will be considered as a group. The sea trouts are mostly schooling, but are sometimes seen in small groups or even alone. They feed inshore over sandy bottoms, especially in tidal inlets and bays, on small fishes and crustaceans. Some get into brackish waters and even go far up rivers. They are highly valued as food fishes, but their flesh is tender and may spoil quickly. This has given some of them the name of "weakfish." These fishes are among the most common fishes in their proper habitat. To swim near a school of them is a thrilling experience. They are swift and graceful swimmers and behave and look very much like trout. The common species are as follows:

WEAKFISH (COMMON SEA TROUT, SQUETEAGUE): *Cynoscion regalis*

Weight: Averages 3 to 6 pounds. Up to 30 pounds very rarely.

Distribution: Massachusetts to Florida and the eastern Gulf of Mexico.

Identification: The color is silvery, becoming lightly olivaceous on the back. The dorsal fins are dusky, and the ventrals and anal are yellow. Spots or blotches form wavy lines running up and back from the lateral line. This fish is one of the gamest of sea trouts.

Similar Species: The spotted squeteague (spotted weakfish), *Cynoscion nebulosus,* averages 2 to 5 pounds and reaches 15 pounds. Its color is silvery with a grayish blue above, and small black spots cover the back and the soft dorsal and tail fins. It ranges from the Chesapeake to Texas.

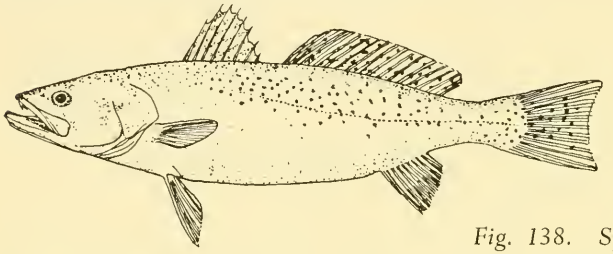


Fig. 138. Spotted squeteague.

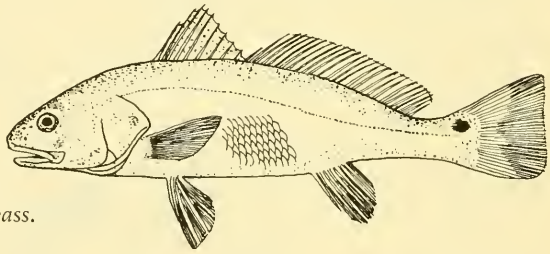


Fig. 139. Channel bass.

CALIFORNIA WHITE SEA BASS (CORBINA): *Cynoscion nobilis*

Size: Up to over 4 feet.

Weight: Averages 5 to 25 pounds. Up to 80 pounds or more.

Distribution: Alaska to Chile.

Identification: The back is steel-blue, and the sides and belly silvery to white. The tail is square cut. The shape is like that of the weakfishes.

Similar Species: The shortfin sea bass, *Cynoscion parvipinnus,* is of a similar coloration but has an S-shaped or concave tail fin and small, dark spots all over the body. It is common only in the Gulf of California.

The little queenfish, *Seriphus politus,* is another bluish-to-silvery fish, but it reaches only a foot in length and has an anal fin as long as its soft dorsal fin. It schools in shallow water over sand from central to Baja California.

TOTUAVA: *Cynoscion macdonaldi*

Weight: This is the largest sea trout. Averages 50 to 100 pounds. Up to 225 pounds.

Distribution: From the head of the Gulf to California to Mazatlán. Present from October to May. Abundant in March.

Identification: The central rays of the tail fin are longest giving the tail fin the shape of a diamond. The color is a coppery or brassy silver. The shape is like that of the other weakfishes.

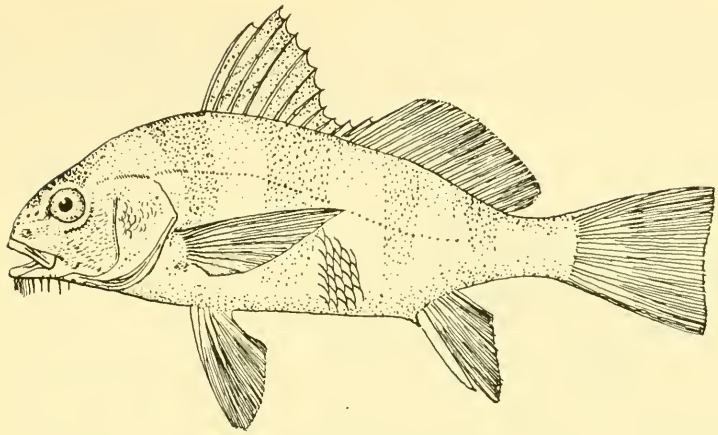


Fig. 140. Black drum.

CHANNEL BASS (REDFISH, RED DRUM): *Sciaenops ocellata*

Size: Up to 5 feet.

Weight: Averages 5 pounds. Common to 15 pounds. Up to 85 pounds.

Distribution: Atlantic Coast from Delaware to Texas, straggling to Cape Cod.

Identification: The shape is slim, but this fish shows the beginnings of the blunt snout common in many croakers. The color is reddish to brassy. The black spot above the caudal peduncle is distinctive.

Habits: This very common and popular fish schools or swims solitarily over sandy shores and bays. It enters brackish and fresh water. It feeds on small fishes and invertebrates on the surface or at the bottom.

BLACK DRUM (SEA DRUM): *Pogonias cromis*

Size: Up to 4 feet.

Weight: Averages over 10 pounds. Up to 146 pounds.

Distribution: Massachusetts to Argentina.

Identification: The body is very heavy, deepest at the shoulder. There are four or five dark crossbands on a dull silver ground color, and the chin bears a series of short pendant barbels.

Habits: This is a very powerful, rather slow-moving fish. It feeds chiefly on shellfish, which are located by the sensitive barbels. Among all members of the family, this fish is the one most famous for the sound it produces, which is a loud drumming noise. The drumming is probably done to attract the opposite sex since it is loudest in the males and done chiefly during the breeding season. Schools swim over beaches, inlets, and bays and migrate during the colder months to offshore waters.

CROAKERS: Genera *Leiostomus, Micropogon, Sciaena, Roncador, Genyonemus, Umbrina*

These are the central members of the family. They are all moderately small fishes which have the fairly deep bodies and the rounded, somewhat projecting

noses of typical croakers. The habits of all are very similar. Small groups or schools swim over sandy or muddy to hard bottoms, especially in the surf, where they feed mainly on small invertebrates. They breed in bays and inlets, usually in early winter.

ATLANTIC CROAKER (HARDHEAD, CORBINA): *Micropogon undulatus*

Size: Averages 1 foot. Up to 30 inches.

Weight: Averages 1 pound. Large at 6 pounds. Up to 8 to 10 pounds.

Distribution: Massachusetts to Texas. Very common south of the Chesapeake.

Identification: There are very small barbels on the lower jaw. Color is brassy, becoming white below. There are large numbers of small dark spots on the sides and back. The flesh is tinged, not unpleasantly, with the flavor of iodine.

Similar Species: The spot, *Leiostomus xanthurus*, has a stouter body shape and no chin barbels. The name is derived from the black, round spot just above the pectoral fin. About fifteen wavy dark bars extend up and back from the lateral line. It ranges from Cape Cod to Texas.

YELLOW-FIN CROAKER: *Umbrina roncador*

Size: Up to 1½ feet.

Weight: Up to 5 pounds.

Distribution: San Francisco to the Gulf of California.

Identification: This fish is a very metallic brassy color to steel-blue or green above. There are wavy lines on the sides extending up and back above the lateral line and horizontally below. The dorsal fins are dark. Other fins are yellow. The shape is like that of the Atlantic croaker.

Similar Species: The California kingfish, *Genyonemus lineatus*, is a silvery to brassy color and has small barbels on the chin. There is a black spot at the pectoral fin base. It reaches a weight of a little over a pound and is found from Vancouver to central Baja California.

The spotfin croaker, *Roncador stearnsi*, is a brassy to steel-gray color and has a dark spot at the pectoral fin base. It averages 5 to 6 pounds and reaches 12 pounds. It ranges from Point Conception to Baja California.

The black croaker, *Sciaena saturna*, is blackish with coppery tints. It has a light band from the dorsal fin to the belly, which is especially apparent in fish which have been in subdued light. It reaches 15 inches and is found from Santa Barbara to the Gulf of California.

NORTHERN KING WHITING (KINGFISH): *Menticirrhus saxatilis*

Size: Up to 1½ feet.

Weight: Averages 1 to 1½ pounds. Up to 3 pounds.

Distribution: Maine to Florida. Common from Long Island to Virginia.

Identification: Members of this genus have a rounded, very projecting snout, a single stout barbel on the chin, an S-shaped tail, and an anteriorly high spiny dorsal fin. Kingfishes have no swim bladder. This species is irregularly blotched.

Habits: The whiting schools over sandy bottoms in shallow water. It feeds mainly on crustaceans and molluscs but will take small fishes. It migrates north and inshore for the warm months. As befits the lack of swim bladder, it often lies on the bottom.

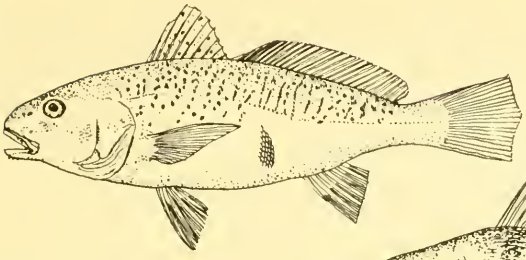


Fig. 141. Atlantic croaker.

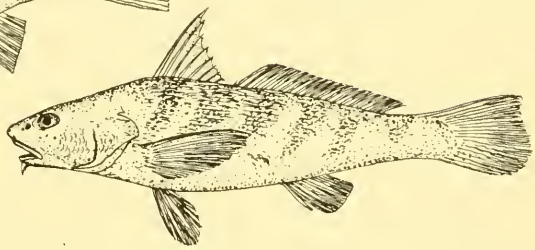


Fig. 142. Southern king whiting.

Similar Species: The southern king whiting, *Menticirrhus americanus*, has six or seven wide dark crossbands sloping forward and downward over the back and sides. It replaces the northern whiting south of the Chesapeake Bay and ranges from New Jersey to Texas. It reaches 15 inches.

The Gulf king whiting, *Menticirrhus littoralis*, has no blotchings or barrings. It reaches 15 inches and 2 pounds, and ranges from the Chesapeake to Texas, tending to replace the southern whiting in the Gulf of Mexico.

The California corbina, *Menticirrhus undulatus*, is a steely blue above, changing to white below, and has wavy, oblique lines of dark spots on the scales. It reaches 2 feet and ranges from San Francisco to the Gulf of California.

RIBBONFISH: *Eques lanceolatus*

Size: Up to 8 to 10 inches.

Distribution: West Indies to southern Florida.

Identification: There are three stripes: a vertical one through the eye, an oblique one from the forehead to the pectoral fin, and a horizontal one from the spiny dorsal to the tail fin. A similar species is shown in figure 12.

Habits: This fish is the exception to all croaker rules. It is a solitary reef fish which can be seen holed up in reefs by day. It is a crustacean feeder, but probably takes small invertebrates in general.

Similar Species: The cubbyu, *Eques acuminatus*, has a size and shape similar to the ribbonfish but has seven narrow horizontal stripes of dark brown running along the silver to gray sides. It ranges from the West Indies to Cape Hatteras.

Surf Fishes: *Suborder Holconoti* (*"furrowed back"*)

This group of twenty-odd species is found only off the Pacific Coast of North America (with three species in Japan). All are small, compressed fishes which closely resemble the porgies, but they do not have such a steep profile. They also have long soft dorsal anal fins composed of many fine rays, and a furrow running along the back on each side of the dorsal fin (hence the name "Holconoti"). The marine species all travel in schools in bays or shallow water over rocky or sandy bottoms, or in surf where they bear their young. A few live in the large California rivers. Surf fishes bear a maximum of a dozen living young which are about one fourth to one third the length of the mother. The species are hard to

distinguish. Barnhart (1936) should be consulted for details. Most of them are crustacean-eaters. They swim actively in much the same way that small perchlike fishes do. Many are of brilliant coloration with the metallic colors of brassy and silver being common.

SURF FISHES: Family Embiotocidae

STRIPED SEA PERCH (BLUE PERCH): *Taeniotoca lateralis*

Size: Averages 8 inches. Up to 15 inches.

Distribution: Alaska to central Baja California. Common north of central California.

Identification: The alternating horizontal bars of orange and green, both metallic, are distinctive. The shape is like that of the rubberlip sea perch.

Habits: This is an exceedingly common fish around rocks, wharves, and in the surf.

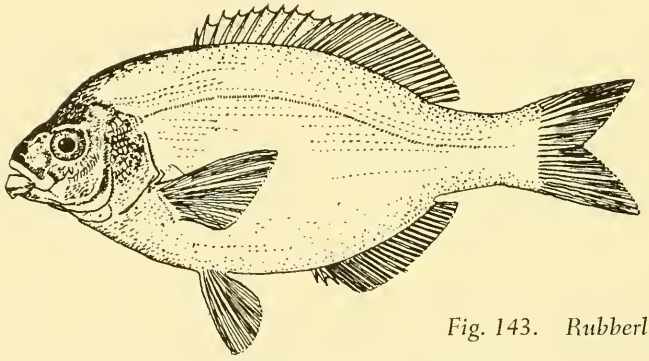


Fig. 143. Rubberlip sea perch.

RUBBERLIP SEA PERCH: *Rhacochilus toxotes*

Size: Reaches 1½ feet. The largest surf fish.

Distribution: San Francisco to San Diego.

Identification: The lips are very thick and drooping.

Habits: Similar to those of the striped perch. This is a valued food fish.

Similar Species: The barred surf perch, *Amphistichus argenteus,* is a very metallic, silvery gray with dark vertical bars and rows of spots above the lateral line. It reaches 12 inches, averages 6 inches, and is common from central to southern California.

The Pacific white perch, *Phanerodon furcatus,* is very abundant in central to southern California and ranges north to Vancouver Island. It has a very large forked tail, and the spiny dorsal fin, which is highest in back and lowest in front, is continuous with the soft dorsal fin, which is highest in front and lowest in back.

Demoiselles: *Suborder Chromides*

Because of its habits, this group can be mistaken for no other. All, with the exception of the reef fish, are pugnacious, very active little fishes, which have

the general shape of a deep-bodied perch. When adult, especially when breeding, they live solitarily or in small groups in holes in reefs or rocks that they have chosen for their homes, vigorously defending these against all comers. They greet the swimmer as he swims near their holes with quarrelsome curiosity and will even harmlessly nip at a finger that is thrust too near. It is in this hole that four hundred to five hundred eggs are laid in a circular pattern. Both parents take meticulous care of the eggs, fanning and picking over them continuously during incubation. Some species lay eggs in the empty shells of conchs. The breeding habits of one species are given by Breder and Coates (1933).

Demoiselles are among the most beautiful and jewellike of reef fishes. Many of them, especially when young, are covered with brilliant, shining blue spots. Some are very confusing, their nomenclature having not yet been straightened out by ichthyologists. This is because several species show a wide and confusing range of color variations, and it is not certain whether these variations are species differences or not. The lateral line of demoiselles stops at the rear end of the soft dorsal fin. The mouth is small although these are carnivorous fishes which eat small invertebrates. They will also scavenge. These bold little fishes depend upon alertness, aggressiveness, bluff, and speed for defense. Their distribution is world-wide in all tropical seas.

GARIBALDI: *Hypsypops rubicundus—Color Plate 6*

Size: Averages 8 inches. Up to 1 foot. This is the largest demoiselle.

Distribution: Southern California to the tropics.

Identification: The brilliant uniform gold color identifies them. The young are green with brilliant blue spots.

Habits: This fish is ubiquitous about kelp and rock. It is a common and constant companion of the underwater swimmer.

SERGEANT MAJOR (NUISANCE, COCKEYE PILOT, PINTANO, JAQUETA): *Abudefduf saxatilis—Color Plate 6*

Size: Up to 6 to 7 inches.

Distribution: West Indies and Bermuda to Florida. West coast of Mexico.

Identification: The black vertical bars on a pale yellow to orange-yellow or greenish ground color are distinctive. There is a dark slate-blue color phase in which the vertical bars are obscured.

Habits: This may be the most common of all demoiselles. The young swarm about every reef and wharf. Adults are much more solitary and seem to stick to reef areas. This is a pugnacious and curious fish, often accompanying the diver. It is very easily chummed.

BEAU GREGORY (YELLOW BELLY, PESCADO AZUL): *Pomacentrus leucostictus—Color Plate 6*

Size: Up to 6 inches.

Distribution: West Indies and Bermuda to Florida. West coast of Mexico.

Identification: The coloration is exceedingly variable. The color plate shows the most brilliantly colored phase—the so-called "jewelfish." This is, however, a confusing term since the young of many other species are covered with very

bright and sparkling blue spots. The colors of this species vary from a dull, uniform, dusky brown to phases like that pictured when blues and yellows predominate. Females are generally browner than males. The shape of the body is less deep than in the previous species, and the size is smaller.

Habits: The authors believe that this fish tends to keep more strictly to holes in reefs than do the previous species. It is not as often seen in groups swimming about and is probably more or less solitary, especially as an adult. The male guards the eggs and is extremely intolerant of the approach of all fishes. The ever-present small wrasses are the chief threats to the eggs and are driven off by pursuit and nips.

YELLOWTAIL DEMOISELLE: *Microspathodon chrysurus—Color Plate 6*

Size: Up to 6 inches.

Distribution: West Indies and Bermuda to Florida.

Identification: The young are covered with brilliant light blue spots. Adults, in contrast to some phases of the beau gregory, lose the spots and acquire yellow lower parts and a brilliant yellow-orange tail.

Habits: Next to the sergeant major, this is the most common West Indian species. Its habits are much like the sergeant major.

REEF FISH (CHROMIS): *Chromis marginatus—Color Plate 6 and Figure 144*

Size: Up to 5 to 6 inches.

Distribution: West Indies and Bermuda to Florida.

Identification: The forked tail fin with outer rays colored black is distinctive. There are two color phases, one light brown and one bright blue. The eye is large and dark.

Habits: This is a reef-living species not found often near shore and at wharfs as are other demoiselles. It has habits unlike others of the family, schooling densely around coral heads and behaving like a small wrasse in its swarming movements. Schools of this fish often follow the swimmer in his journeys under water. The forked tail is often opened and closed, the black outer rays appearing like scissors.

Similar Species: The West Coast form in tropical waters is the blacksmith, *Ayresia punctipinnis.* It is very similar in appearance and habits to the East Coast species, but it is of dark coloration. Other species are found near reefs the world over.

Labroid Fishes: *Suborder Pharyngognathi* (*"throat teeth"*)

There are two largely tropical and distinct families, both of which have heavy pharyngeal teeth with which they crush their food.

WRASSE: Family Labridae

These very abundant and varied fishes are chiefly typical of tropical seas, but they are also found in the temperate zones. All have a very characteristic buck-toothed profile, which is the result of projecting caninelike teeth in the front of the mouth, protrusible jaws, and thick lips. They are variable in body form, but most are elongate, brightly colored, and have a continuous dorsal fin in which the spiny part is long. The anal fin reflects the soft dorsal in size

Fig. 144. Reef fish, Chromis marginatus, *swarm over reefs in schools, their forked tails reminiscent of barn swallows. Stinging coral,* Millepora, *and various gorgonians are below the reef fish.*

and appearance. Several facts make this a difficult family to comprehend. There are 450 species in the world, many of which are very confused in both common and scientific names. Furthermore, many of the species change greatly in shape and coloration during growth. During the breeding season the adults take on special nuptial colors. The basic color seems to be green, but many of them are marked with yellow, blue, or red.

The smaller ones are grouped under the terms "slippery dick" or "razor fish." They are the most common of all reef fishes, swarming like birds literally everywhere. They eat shellfish, molluscs, and other invertebrates, which are crushed in the heavy pharyngeal teeth.

De Latil (1955) describes the breeding habits of some Mediterranean wrasse. They build nests of stones and seaweed and defend these avidly. Egg-laying is preceded by a strange nuptial dance in which the breeding pair advances and retreats in a vertical position, waving their pectoral fins and opening and closing their mouths. The eggs and milt are shed, and then the seaweed and stones are pushed around the eggs. These little piles of seaweed and stone are common in summer in reef areas. The nest is defended until hatching time. The nature of nesting material would be expected to vary greatly from place to place.

Most wrasse, big and small, are not schooling, but usually swim near or with others of their own kind or as part of a motley crew composed of species of similar habits.

TAUTOG (BLACKFISH, OYSTERFISH): *Tautoga onitis*

Size: Up to 3 feet.

Weight: Averages 2 to 4 pounds. Up to 22 pounds.

Distribution: Maine to the Carolinas. Common from Cape Cod to Delaware.

Identification: The snout is blunt and the body heavy. Ground color is brown to black or olivaceous. There are irregular blotches, and the conspicuously whitish chin makes a good field mark.

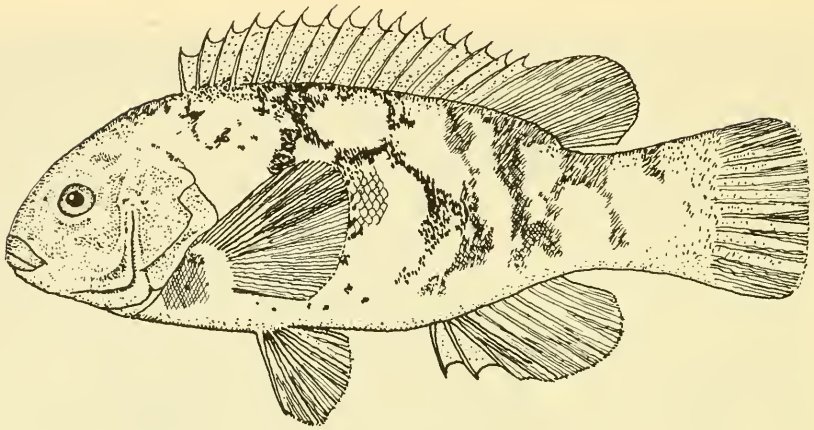


Fig. 145. Tautog.

Habits: This familiar fish is very common about rocks in shallow water near shore. It is not easily frightened and will round rocks just ahead of the swimmer, shortly returning to its accustomed place from which it was driven. Several are usually seen together, but it is not a schooling species. It is a mollusc- and crustacean-eater. Tautogs lay buoyant eggs in June and July in fairly deep water.

Similar Species: The cunner (bergall), *Tautogolabrus adspersus*, is the most northern wrasse. Its habits are much like those of the tautog, and the two species are often seen together. The head is more pointed than that of the tautog, and the color is a mottled brown to olivaceous. It reaches 15 inches and ranges from Labrador to the Chesapeake.

CALIFORNIA SHEEPSHEAD (REDFISH): *Pimelometopon pulcher—Color Plate 8*

Size: Up to 3 feet.

Weight: Up to 25 pounds.

Distribution: Monterey Bay to the Gulf of California.

Identification: This is a very bizarrely colored fish. The males have a black head and black rear parts with an orange mid-body. The females are uniformly reddish to black and occasionally blotched. The scientific name means "beautiful, fat forehead."

Habits: This is an inshore fish of the rocks and kelp beds. Its habits are much like those of the tautog, but it is a pugnacious fish, fighting both its own species and others as well.

HOGFISH (CAPITAN): *Lachnolaimus maximus—Color Plate 8*

Size: Up to 2½ feet.

Weight: Averages 4 pounds. Up to 20 pounds.

Distribution: West Indies to Florida.

Identification: The silhouette is completely unique with steep profile, deep body, and long first dorsal rays. The color varies from a reddish blotched pattern (*Color Plate 10*) to a rather plain "red-fronted" phase.

Habits: This fish swims singly or in small groups in open spaces, such as

gorgonian beds, in a stately fashion which befits its appearance. It is an excellent food fish although its sale on the market was at one time forbidden due to the supposedly poisonous character of the flesh. This fish is easily chummed with bits of broken sea urchin or mollusc.

Similar Species: The Spanish hogfish, *Bodianus rufus* (*Color Plate* 8), is less deep-bodied than the hogfish and has no long dorsal fin extensions. It swims solitarily over reefs and is West Indian but somehow lacks the dignity of the hogfish. It reaches 1½ feet and is mostly smaller. The color is distinctive, being greenish to crimson above and forward and golden below and to the rear.

BLUE-HEAD (KING SLIPPERY DICK): *Thalassoma bifasciatum—Color Plate* 8

Size: Up to 6 inches.

Distribution: West Indies to Florida.

Identification: Mature males are conspicuously collared with two black bands. The head is blue, and the body and tail are greenish yellow. The females are uniformly yellow with black blotches in a row on the sides.

Habits: This is the most common of all West Indian reef fishes. Females and young, brightly yellow, swarm everywhere. The males are less common but are still very abundant. Groups of these fish often will follow a swimmer. They are very easily chummed. They graze over reefs on a wide variety of small invertebrates. Like many other small wrasse, the blue-head buries itself in sand by night. Longley and Hildebrand (1941) state that the young frequently peck at larger fishes such as tang, chubs, demoiselles, and, most commonly, skipjacks. Presumably, this is done to remove ectoparasites from these fishes, but oddly enough no parasites have been found in stomachs of blue-heads.

Similar Species: The senorita, *Oxyulis californica,* reaches 7 inches and is found from Monterey to Guadalupe Island. It frequents kelp and rocks and is of a kelp-brown color, with cream below and a black blotch at the tail base.

SLIPPERY DICKS AND RAZOR FISHES: *Genera Iridio and Xyrichthys*

There are many species of these fishes. They are all of small size, averaging about 6 inches, but some reach 1½ feet, though rarely. Most of them are pearly and iridescent with flecks and blotches of many shades of color on the body. The

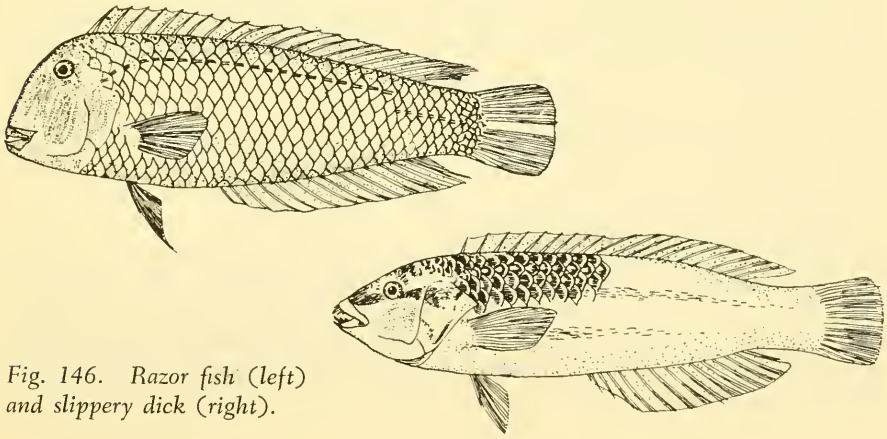


Fig. 146. Razor fish (left) and slippery dick (right).

razor fishes, *Xyrichthys,* are much compressed and have a rounded forehead which is often so compressed as to have a sharp leading edge. No attempt will be made to separate the numerous West Indian species. There is only one southern Californian form, the so-called "parrot fish," *Iridio semicinctus.* Razor fishes and slippery dicks build nests of sand or coral in which to lay their eggs. Most of the smaller ones bury themselves in sand or stones, where they are able to hide from enemies or sleep at night. The razor fishes, in particular, are adapted to living near sandy bottoms. They build homes of bits of debris and keep them in constant repair. When pursued, they are able to move freely under sand. Agility under sand is due mainly to their knife-edged forehead and compressed body.

PARROT FISHES: Family Scaridae

The large scales, bright colors, heavy bodies, and lumbering movements of parrot fishes are strongly reminiscent of huge goldfishes. The name is derived from the parrotlike beak of fused teeth in the mouth. These, even more than wrasses, are typical of reefs, being found almost no place else. About reefs, they are the most common large fishes. They are nonschooling but are gregarious, swimming with their own kind, near relatives, or near other reef fishes, such as the doctorfishes. The strong beaks, which can snip a stout wire in two, are used to graze over reefs for both animal and plant substances. The diver will often hear them crunching on coral. After a meal, large ones often stand erect and let small wrasse clean the coral fragments and sand from their heads and mouths.

Parrot fishes will usually not allow close approach. It is far better to let them approach the swimmer; they are skittish but still moderately curious. If approached closely, they swim away in a very characteristic manner, using a flapping motion of their large pectorals and using the tail for little but steering. They occasionally roll ever so slightly from side to side in order to peek back at their pursuer, first over one shoulder then the other. Swimming like this, they do not move speedily, but they can easily outdistance the swimmer. Like many other fishes, parrot fishes learn very quickly to avoid a man with a spear. Parrot fishes become very large and heavy and enter very shallow waters occasionally. They are frequently gaudily colored with green, red, yellow, or blue. There are over one hundred species of parrot fishes the world over. Ekman (1952) says there are none on the West Coast of North America, but Jordan and Everman (1900) report one rare species. Some are quite small, attaining a maximum size of under 1 foot. Large ones seem to have few enemies.

RED PARROT FISH (LORO COLORADO): *Sparisoma abildgaardi—Color Photograph*

Size: To 1 foot.

Distribution: West Indies to Florida.

Identification: Members of this genus are all rather small and have a lower jaw that is as long as the upper. The scales on the head are few and large, and the beak is white or rosy. This species has bright red fins and a distinctive coloration in which the scales are clearly outlined in black. Some scales are white, giving the fish a sparkling, mottled appearance, but spotting and blotching can vary considerably.

Habits: This fish and similar parrot fishes swim with other parrot fishes or with tang and goatfish, grazing about reefs, and on the sand near reefs, on animal and plant substances.

Similar Species: The mud parrot fish, *Sparisoma flavescens,* is a dingy gray-brown to olivaceous. The scales are clearly outlined. It is small, up to 1 foot, and found in the West Indies.

The green parrot fish, (loro verde) *Sparisoma viride* (*color photograph*), is very common in the West Indies. It is a dull greenish color, but the tail is a brilliant, bright green with several large orange scales at its base and a blue posterior margin. It reaches 1½ feet or more.

BLUE PARROT FISH (CLAMACORE): *Scarus coeruleus—Figure 147*

Size: Up to 3 feet. Averages 1 to 1½ feet.

Distribution: West Indies to Florida. Straggles rarely to the Chesapeake.

Identification: The members of this genus have a lower jaw that is shorter than the upper. The beak is either whitish or rosy, and the scales on the head are rather numerous. Some of them grow to large size. This species has the mouth placed noticeably under the snout and is a beautiful, uniform sky-blue in color. Older individuals have long outer tail-fin rays and a very pronounced swollen snout.

Habits: The larger members of this genus are lumbering in their movements as are the larger members of the following genus (*Pseudoscarus*). This species has the widest range and is perhaps the most common of all parrot fishes, particularly over outer reefs. It may often be seen swimming in small groups around the base of coral heads, feeding in sand or on the coral.

Similar Species: The blue parrot fish (oldwife, vieja), *Scarus vetula,* is a very striking predominantly blue fish. The jaws are edged with light blue and red. The tail and pectoral fins are edged with a reddish color, and the pelvic fins are yellow to red. It reaches 2 feet or more in length and is common in the West Indies.

The white-banded parrot fish, *Scarus gnathodus,* is a wine-brown with a very wide lateral white stripe. It grows to a little over a foot and is fairly common in the West Indies.

The painted parrot fish (ribbon parrot fish), *Scarus punctulatus,* is a lovely little West Indian fish which is commonly seen in small groups. It reaches only 10 to 12 inches in length at most and has two green stripes on the head above and below the eye.

The mud-belly, *Scarus croicensis* (*color photograph*), reaches only 10 inches, is brownish to slate-blue with a light belly, and usually has two light bands running horizontally on the sides and a yellowish area on the nose. It is fairly common from the West Indies to Florida.

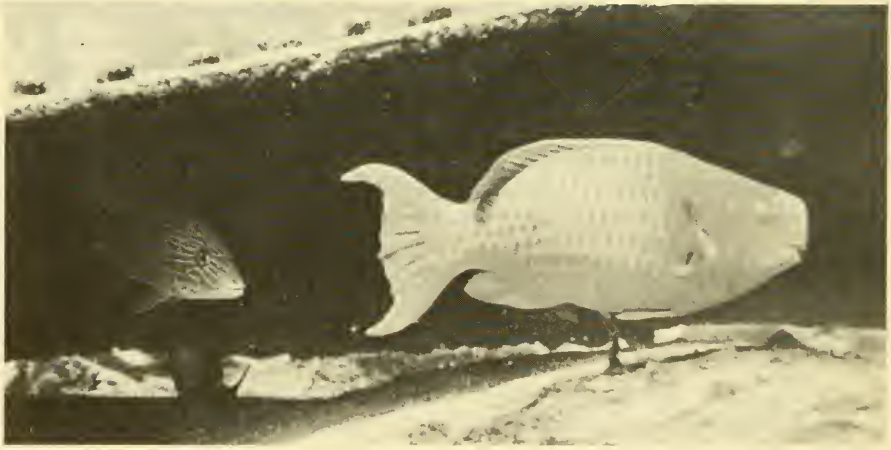
RAINBOW PARROT FISH (GUACAMAIA): *Pseudoscarus guacamaia—Color Plate 8*

Size: The largest parrot fish. Averages a little over a foot. Up to over 3 feet.

Distribution: West Indies to Florida.

Identification: Members of this comparatively small genus are like *Scarus* species but have distinctly green or blue beaks. This species is of very gaudy coloration, especially when adult. The young are greenish with a brown spot

Fig. 147. Top. The indigo parrotfish, Pseudoscarus coelestinus, *second largest of the North American parrotfishes, probably reaches 2½ feet in length. Bottom. The blue parrotfish,* Scarus coeruleus, *is a beautiful sky-blue color and develops a large fleshy lump on the nose when it matures. A blue-striped grunt scowls from under part of a wreck in the background.*



on each scale. The belly and throat are reddish brown. The vertical fins are edged with blue-green. As they get older, they take on a reddish-brown color anteriorly and are greenish posteriorly, as pictured, but the coloration is always subject to great variation.

Habits: Like those of the genus *Scarus.*

Similar Species: The indigo parrot fish (purple parrot fish, wine-colored parrot fish), *Pseudoscarus coelestinus* (*fig. 147*), is a very dark blue or purplish parrot fish with the jaws, forehead, and base of the spiny dorsal fin colored a very bright greenish blue. The authors found it common in the Bahamas, and the individual shown in the photograph was a minimum of 2 feet long.

Scaly-Fin Fishes: *Suborder Squamipinnes* ("*scaly fin*")

Very few fishes can match the beauty of color, form, and movement of these mostly tropical fishes. They glide effortlessly through the water, their lustrous, velvety bodies never failing to impress the diver. There are three quite distinct families. All possess dense scalation on the vertical fins, which adds to the soft and velvety appearance. All are strongly compressed and deep of body, and most use the pectoral fins in a flapping manner to aid in their movements. This method of propulsion is not so exclusively used as it is in the parrot fishes. The mouths of the scaly-fins are small and the teeth small and brushlike (except in tangs), so most are invertebrate- and algae-eaters exclusively. Various shades of yellow, blue, and black are predominant colors. Their distribution is world-wide, chiefly over and around reefs.

SPADEFISHES: Family Ephippidae

These fishes are a bit off the beaten track for scaly-fin fishes. The color is predominantly silvery, and there is a prominent spiny dorsal fin. Spadefishes school rather densely inshore and about reefs, wrecks, rocks, and pilings. They swim faster than do other scaly-fins and more in a typical "fishy" manner than most scaly-fins do, using the tail for propulsion. There are few species, mostly in tropical seas.

SPADEFISH (PAGUALA): *Chaetodipterus faber*–*Color Plate 7*

Size: Averages 1 foot. Up to 3 feet.

Weight: Up to 20 pounds.

Distribution: Cape Cod to Brazil. Most common in the West Indies.

Identification: The silvery to whitish color with black crossbands is distinctive. As the fishes get larger, the bands disappear. The silhouette is the best field mark.

Habits: The food consists primarily of invertebrates, mainly crustaceans. Ctenophores also are eaten.

Similar Species: Chaetodipterus zonatus is the similar spadefish of the western coast of Mexico. It ranges rarely as far north as San Diego.

BUTTERFLY FISHES AND ANGEL FISHES: Family Chaetodontidae

Size is the characteristic which separates the butterfly and angel fishes. The former are small and very active, almost birdlike in their movements, and are mostly seen traveling in pairs. The latter are larger, have stately movements, and travel singly, in pairs, or in small groups. The young of both are usually very different from the adults in pattern and in coloration. These are among the most typical of reef fishes, found throughout the world.

BUTTERFLY FISHES: *Chaetodon* species

The habits of these species are so similar that they had best be considered as a group. All are very active fishes and have the flitting movements of a butterfly, hence their name. They are exceedingly brightly colored, principally with yellow and black. Owing to their small size and their lack of great speed, it would be expected that they would be secretive, but they are not. They depend on extreme alertness and activity, as do the demoiselles, for safety. Many of them also add

two interesting types of protective coloration, both of which create the illusion that they are swimming backwards, thus forcing a predator to miss its mark. First, the eye is camouflaged by a vertical line which runs through it. The eye is the most difficult part of the body to hide since it is round, moving, and shiny. Many animals, therefore, have evolved a line through it or a mark over it. The raccoon, wood frog, and shrikes are familiar examples of this. The butterfly fishes not only destroy the outline of the forward, true eye, but frequently add a false eye to the rear in the form of a large, dark, usually ocellar, spot. A predator aiming for this "head end" with its large "eye" is deceived and comes up with nothing but a mouthful of water as the little fish scampers off unexpectedly in a direction which looks backward.

Butterfly fishes have pointed, extended snouts with the small mouth situated at the end. With this snout they are able to poke about every nook and cranny of reefs or rocks for their small invertebrate or plant food. They commonly eat parasites attached to other species. Some large predators even allow them to probe in their throats for parasites. The common East Coast species are three in number. There are many similar Pacific species, mostly Polynesian.

BANDED BUTTERFLY FISH: *Chaetodon striatus—Color Plate 6*

Size: Up to 6 inches.
Distribution: West Indies to Florida.
Identification: There is no rearward spot. The color is a very pale yellow or white crossed with vertical black bands.

COMMON BUTTERFLY FISH: *Chaetodon ocellatus*

Size: Up to 8 inches.
Distribution: West Indies to Florida. Straggles to Cape Cod.
Identification: This is a yellow fish with a dark line through the eye and usually with a dark nonocellar spot at the base of the soft dorsal fin, but this may be missing or enlarged (in young fish) to form a vertical band. The shape is like that of the four-eyed butterfly fish.

FOUR-EYED BUTTERFLY FISH: *Chaetodon capistratus—Color Plate 6 and Color Photograph*

Size: Up to 6 inches.
Distribution: West Indies to Florida. Straggles to Cape Cod.
Identification: The large ocellated spot on the rear part of the body is unmistakable. The body is delicately yellow to white and covered with very fine rows of spots. This is the most common West Indian species.

ANGELFISHES: Genera *Pomacanthus, Holocanthus* and *Angelichthys*

These large and exceedingly lovely fishes are constant sources of the aesthetic inspiration which many divers seek under water. Their movements can only be described as majestic and stately. As the diver approaches them, they will at first face him, swim toward him a bit, then turn in an arc so as to present the full beauty of the velvety sides and fins, lending themselves admirably to photography. These fish will occasionally do this over and over, coming at the diver first from behind a coral, then from out of a hole.

In habits, the angelfishes are really only larger editions of butterfly fishes. They also very often travel together but usually in small groups of up to half a dozen. Some are most often seen alone. The brushlike teeth aid them in grazing over reefs for invertebrates and plants. All of these fishes have a large sharp spine directed back from the preoperculum, which can inflict injuries when the fish is handled. The mouth and lips are usually a different color than the head, giving some of them a Jolson-in-blackface look. The dorsal and anal fins are elongated at the corners. The species are as follows:

BLACK ANGELFISH (CHIRIVITA): *Pomacanthus arcuatus–Figure 148*

Size: This is the largest angelfish, reaching 2 feet.

Distribution: West Indies to Florida.

Identification: Members of this genus have very deep bodies, almost round, and the dorsal spines are obscure. This is a grayish species with each scale bearing a small black spot which gives a gray, velvety lustre. The inside of the pectoral fin is bright yellow, and this color is flashed as the fish swims with the aid of that fin. The mouth is conspicuously white. The young are black with vertical yellow bars that disappear with age. This species is usually seen in groups of three to six fish, swimming in rather open water near reefs.

Similar Species: The French angelfish, *Pomacanthus paru* (*Color Plate 7*), reaches a length of 14 inches and is found in the West Indies north to Florida. The color is black with each body scale outlined with yellow. The base of the pectoral fin is yellow. The young with their vertical yellow stripes (*Color Plate 7*) are common and striking reef fish. The West Coast member of this genus is *Pomacanthus zonipectus* and is found south of Mazatlán.

ROCK BEAUTY (VAQUETA DE DOS COLORES): *Holocanthus tricolor–Color Plate 7*

Size: Up to 1 foot.

Distribution: West Indies to Florida Keys.

Identification: The very striking color pattern of a yellow head, belly, and tail combined with a black body is distinctive. The shape is somewhat rectangular, and the dorsal spines are small but noticeable. This fish is usually seen singly in and about holes in reefs.

QUEEN ANGELFISH (ISABELITA): *Angelichthys ciliaris–Color Plate 7*

Size: This is as long a fish as the black angelfish, reaching 2 feet, but its lesser body depth makes it appear smaller.

Distribution: West Indies to Florida.

Identification: The sides are predominantly yellow with a blue cast. This blue may become quite dark at times. The dorsal and anal fins are yellow, edged with blue. The pectoral and caudal fins are yellow. There is a very distinctive black ocellus ringed with blue on the forehead. The blues on this fish are interference colors and are more iridescent than the yellow pigment colors. The shape is somewhat rectangular, and the spines of the dorsal fin are noticeable. The young show a dark bar through the eye and pale bars posteriorly. This fish is usually seen singly about coral heads.

Similar Species: The common angelfish, *Angelichthys isabelita,* is found from the West Indies to Florida and is identical to the blue angelfish of Bermuda. It

Fig. 148. Top. The ocean triggerfish, Canthidermis sabaco, *mistakenly called "turbot," moves through the water by flapping its dorsal and anal fins from side to side. It is exceedingly curious and found mostly over offshore reefs. Bottom. Black angelfishes,* Pomacanthus arcuatus, *might easily pass for Jolson-in-blackface. The sharp preopercular spine is shown on the individual to the left. This pod is travelling over a meadow of sea plume gorgonians.*

has no ocellar spot on the forehead, and the pectoral and caudal fins only are edged with yellow. The young are barred as are the young of the queen angelfish.

TANGS: Family Acanthuridae

There are many species of these tropical reef fishes found throughout the world. All are characterized by their silhouette, in which the dorsal and ventral curvatures and fins are very similar, giving the body an ovoid shape. Tangs are no less velvety than angelfish in appearance. They have a formidable weapon in the scalpellike vertebral spine, which is usually folded forward in a groove in the tail, but which may be erected and used in a slashing manner to inflict deep cuts on an adversary. This weapon has given them the names of "surgeonfish" or "doctorfish." Among Spanish-speaking peoples they are known as "barberos" or "medicos." In early days, it was the barber who practiced phlebotomy, or blood-letting, and who was the local general practitioner.

Tangs usually swim in small groups, often with parrot fishes, and often use the pectoral fins in a flapping manner for propulsion, though this kind of propulsion is not as predominant as in parrot fishes. The teeth are different from those of other scaly-fin fishes. A single series of incisorlike teeth is present in each jaw. These are used to scrape away plant and animal substances from the reefs on which they graze. Dark brown and blue colors predominate. The young are colored very differently from the adults.

BLUE TANG (BLUE DOCTORFISH, SURGEONFISH): *Acanthurus coeruleus*—*Color Plate 7*

Size: Averages 8 inches. Up to 1 foot.

Weight: Up to 1 pound.

Distribution: West Indies to Florida. Straggles to New York.

Identification: The blue color is dark, exceptionally velvety, and very hard to catch on film, requiring more exposure than would appear necessary. This color, however, is variable, becoming very pale over a sandy bottom, so the very deep, almost circular shape and the tail lancets of white are the best marks.

The young of this fish, formerly described as a separate species, is an exceedingly brilliant, jewellike yellow fish up to the time it is about 3 inches or so long (it has been reported to 6 inches). It is common in the company of wrasse about coral heads and has the shape of a butterfly fish, but the tail spine gives it away. It tends to keep close to the protection of the coral.

Habits: Tangs are found in groups, singly, or swimming with other reef fishes (parrot fishes commonly). They graze, much after the manner of parrot fishes, and show some of the same wary habits, though less pronounced.

Similar Species: The doctorfish, *Acanthurus hepatus* (*Color Plate 7*), is a West Indian species which also goes as far north as Cape Cod accidentally. It is less deep of body than the blue tang and varies from a dark to light brownish color. The lancet on the tail is dark. This fish reaches 10 inches.

The ocean tang, *Acanthurus bahianus,* also has dark and light brown phases but keeps more offshore, and large specimens have the upper lobe of the caudal fin elongated into a filament. Its range is the West Indies, accidentally to Cape Cod, and it commonly reaches 1 foot.

The barbero negro, *Acanthurus crestonis,* is found from Mazatlán south and is usually very dark in color.

Plectognaths: ***Suborder Plectognathi*** **(*"jaws woven together"*)**

Here are united three rather distinct groups which have formerly been considered separate suborders: (1) the Sclerodermi ("hard skin") or triggerfishes and filefishes, (2) the Ostracodermi ("box skin") or trunkfishes, and (3) the Gymnodontes ("naked tooth") or puffers and porcupine fishes. But because of the common origin of these fishes from scaly-fin fishes and because of several trends which these three groups show in common, the splitting of this group in three parts may not be justified. All show a very reduced gill opening, a trend definitely present in some scaly-fin fishes, notably tangs. All reduce or lose the ventral fins. All have lost typical scales, having plates or spines in their place. All have several jaw bones fused, hence the term "Plectognathi." Many, especially the gymnodonts, develop poisonous alkaloids in their flesh or viscera. The Polynesian maki-maki or deadly death, *Tetraodon hispidus,* has deadly flesh. The flesh of porcupine fishes causes a nerve poisoning called "ciguatera." Some, however, are good eating. Northern puffer tails are sold as "sea squab." The plectognaths all have small mouths and are feeders on small invertebrates or marine vegetation.

TRIGGERFISHES: Family Balistidae

The word "balistes" means "crossbow" and is applied to the triggerfishes because of the very odd arrangement of the spiny dorsal fin. The large first spine locks erect into place and can be released by depressing the third spine. These compressed, deep-bodied fishes have hard scales imbedded in the skin and no mucus and therefore feel decidedly leathery. The bones of the ventral fins beneath the skin form an erectile flap which gives the belly outline a very odd shape, pointed and deep just ahead of the anal fin. The soft dorsal and anal fins are much alike in size and shape and are used in propelling the animal. They flap from side to side, both fins flapping first to one side then to the other. This is especially noticeable in the ocean triggerfish, which keeps more to open water than the others and also swims more constantly. These are primarily tropical reef fishes of world-wide distribution.

COMMON TRIGGERFISH (CUCUYO): *Balistes capriseus—Color Plate 9*

Size: Averages 10 inches. Up to 20 inches.

Weight: Up to 4 pounds.

Distribution: West Indies to Cape Hatteras. Strays to New York. Western coast of Mexico.

Identification: Dull brown with mottled sides when near cover such as sargasso. Plain gray in open water.

Habits: This fish is found either singly, in small pods, or swimming with other small fishes such as grunts. It keeps to reefs, rocks, and hard bottoms, swims actively, and feeds on worms, crustaceans, and molluscs primarily. The young keep to the shelter of sargasso weed or floating objects.

QUEEN TRIGGERFISH (OLDWIFE, COCINO): *Balistes vetula—Color Plate 9*

Size: Averages 1 foot. Up to 1½ feet or more.

Distribution: West Indies to Florida, straggling to New York.

Identification: This is a brilliantly marked species which shows great variation in intensity of color, matching the lightness or darkness of the bottom, but which always has iridescent blue stripes on the head and an iridescent blue tail base. The back is usually blue to green and the throat and belly orange. The adults have the soft dorsal fin and corners of the tail fin elongated into long filaments.

Habits: This is a fish of hard bottoms and reefs. It is usually seen singly and acts much like some angelfishes, such as the rock beauty, in its almost sinuous movements. Its lustrous colors are shown off to great advantage as it swims in and out of holes in reefs.

Similar Species: The ocean triggerfish or turbot, *Canthidermis sabaco* (*fig. 148*), is a uniform dark gray and swims just fast enough to keep out of the reach of the swimmer, chiefly around outer reefs. It is insatiably curious. The authors have chased them away just to see how long it would take them to return. As soon as they were ignored, back they would come to look the situation over. This is one of the largest triggerfishes, reaching 2 feet and ranging through the West Indies and off Florida.

The Pacific triggerfish, *Verrunculus polylepis*,. is another very large species reaching 2 feet or more in length. It varies from dark to light brown in color and is found from Catalina Island to Baja California.

A very pretty East Indian and West Mexican species, of predominantly violet coloration and with dark lines on the cheeks and longitudinal rows of blue spots on the sides, is *Xanthichthys lineopunctatus*. It reaches 10 inches and rarely strays as far north as San Diego.

FILEFISHES: Family Monocanthidae

These are degenerate offshoots of the triggerfishes in which the dorsal fin has been reduced to one long spine. The skin is rough and was formerly used as shagreen. The ventral outline is even more bizarre than in triggerfishes, sometimes being anteriorly very deep. With the change in shape of the dorsal and anal fins, to low and long rather than high and pointed as in triggerfishes, there is a change in the method of propulsion. Waves pass down these fins toward the rear to move the fish slowly forward (*fig. 149*). The tail fin, though large, is kept motionless and folded and is usually not used at all. The very small mouth, often at the end of a long snout, is used to graze over pilings for both plant and animal substances. Most of these fishes keep to the protection of wharfs, rocks, or reefs and assume odd positions, head up or down, reminiscent of the trumpetfish, as they graze over the rocks or pilings for food. They are found in all tropical and some warm temperate seas.

ORANGE FILEFISH: *Alutera schoepfi—Color Plate 9*

Size: Averages under a foot. Reaches 2 feet.

Distribution: West Indies to Maine and Texas.

Identification: The color is a mottled orange to brown or olivaceous. It is covered with dark spots.

Habits: This is a typical fish of inshore rocks, pilings, and seaweed. So slow, awkward, and unfishlike are its movements and so close to rocks does it stay, that it can quite easily be overlooked. The adults usually prefer inshore waters,

Fig. 149. This scrawled filefish, Alutera scripta, *measured about eighteen inches. It has a very large tail fin which it keeps folded, propulsion being accomplished by means of sine waves travelling rearward in the dorsal and anal fins.*

especially over eelgrass-covered sand, but Crawford and Powers (1953) report that they sometimes school several miles offshore. The resemblance to plant leaves is striking, and groups of these fishes have been observed to form a rosette pattern with the head of each fish pointing inward, accentuating the resemblance to floating seaweed. The young are frequently found in sargasso weed or among other floating objects.

Similar Species: There are several smaller filefishes on North American coasts. The common filefish, *Monacanthus hispidus,* is most common in eelgrass and can change its color to match its environment—mottled green in eelgrass, brown in sargasso, pale gray over sand. It reaches 10 inches and is found from the West Indies as far north as Maine.

The scrawled filefish, *Alutera scripta* (*fig. 149*), is a large species, reaching 3 feet in length, which is found very widely in tropical seas of the world. It has a concave profile to the snout, is covered with light blue and small black spots, and has a very long tail which is usually kept folded. This fish is very curious and, like the ocean triggerfish, swims slowly around and around the swimmer up to a distance of about 10 feet, never seeming to satisfy its curiosity. It keeps to rather open waters over hard bottoms.

The unicorn filefish, *Alutera monoceros,* reaches a length of 2 feet and is cosmopolitan in warm seas. It looks much like the scrawled filefish, but has a convex profile, mottled body, and shorter tail.

TRUNKFISHES: Family Ostraciidae

These little fishes have resorted to the same means of protection as have the turtles, that of enclosing almost the whole body in a shell. The shell is composed of fused, six-sided, bony scales, and it is usually triangular in cross section.

This has restricted the fishes' movements greatly. These fishes, not having flexible operculums, utilize movements of the pectoral fins to help circulate water through the gills. Propulsion is accomplished by rapid sculling motions of the dorsal and anal fins, the tail fin being used only in moments of dire stress. As the swimmer approaches one of these fish, it will at first face forward, then turn around and flee with all its might. In flight, its dorsal and anal fins work very hard and comically, moving the fish at a speed well under that of a swimmer with flippers. The fish will rock from side to side every so often to look back over its shoulder at its pursuer. It somewhat resembles parrot fishes in this respect. After a while, discovering that escape is not possible, it will come to rest near some protecting ledge or hole.

Trunkfishes have very small mouths. They eat small invertebrates and plant substances. Their distribution is world-wide in tropical seas.

COWFISH: *Lactophrys tricornis*–*Color Plate 9*

Size: Averages 8 inches. Up to a little over 1 foot.

Distribution: West Indies to Cape Hatteras. Straggles to Massachusetts.

Identification: There is a spine over each eye and two spines near the rear end of the shell. The coloration is a blotched green with beautiful iridescent yellow and blue spots.

Habits: This is a bottom fish found around reefs, rocks, and harbors. When badly frightened, it assumes an iridescent, light blue color.

Similar Species: The shellfish *Lactophrys bicaudalis* is a tropical reef species reaching a length of 16 inches. It ranges throughout the West Indies and north to Florida. There are spines on the lower rear angles of the shell, which is light brown or greenish and covered with round, dark spots.

Fig. 150. The trunkfish, Lactophrys trigonias, *moves slowly by flapping its dorsal and anal fins. It steers with the tail fin spread fan-shaped behind. For protection it depends on its hard shell of fused, bony scales and adaptive coloration.*

The common trunkfish, *Lactophrys trigonias (fig. 150)*, is like the shellfish in distribution and coloration, but is smaller and has black bases to the fins.

A species with a spine over each eye, *Ostracion diaphanum,* is reported by Barnhart (1930) to have been picked up dead on southern California beaches. It should be looked for.

PUFFERS: Family Tetraodontidae

These fishes possess the almost unique ability, along with the swell shark, of inflating themselves with either air or water or both so that they assume an almost globular shape. They are able to do this very quickly, and by this means they make themselves larger to discourage enemies which would otherwise attack them. When swollen with air, they bob helplessly, belly up at the surface. Deflation is accompanied by ludicrous belching noises and bubbling at the mouth.

Puffers can make a grinding noise by rubbing their teeth together. The teeth of puffers are fused into a beak which is divided by a median suture, hence the name "Tetraodontidae," meaning "four-toothed." They eat shellfish such as crab and molluscs as well as other invertebrates, cracking them with this beak. They swim by using the pectoral, dorsal, and anal fins principally. Puffers are mostly small, active little fishes which nose about reef and sandy bottom areas in tropical seas.

Many species develop poisons in their liver and gonads, or more rarely in the flesh. It is not known what causes some puffers to become poisonous and some not. The eggs are known to carry poison, and if a puffer ate its own eggs, as some are known to do occasionally, this might cause the liver or even the flesh to become poisonous also. However, the nature of fish poisoning is very poorly known (Chapter 4).

RABBITFISH (SMOOTH PUFFER): *Lagocephalus laevigatus—Color Plate 9*

Size: Up to 2 feet. Largest of the puffers.

Weight: Up to 7 pounds.

Distribution: West Indies to Cape Hatteras. Straggles to Cape Cod.

Identification: The color is silvery, becoming greenish above. The head is blunt compared to other puffers. There is a fold of skin on the lower body especially posteriorly.

Habits: Rabbitfish are not able to distend their bodies as greatly by swelling as other puffers, a fact no doubt related to their already large size. They swim over a wide variety of sandy or hard bottoms and are found in harbors, but they prefer shallow channel waters. Their food consists of crustaceans and molluscs.

SOUTHERN PUFFER: *Spheroides spengleri—Color Plate 9*

Size: Up to 1 foot or more. Mostly seen under 8 inches.

Distribution: West Indies to Florida. Straggles to Massachusetts.

Identification: There are a series of black spots along the sides. The tail fin has two black bands, one at the base and one at the tip.

Habits: This species can distend itself to an extreme degree. Normally it is quite slim. Even the young are able to swell up, forming curious little pea-sized balloons. This is a common fish in shallow waters in harbors and over sandy bottoms. It has been seen attacking large crabs in groups, one fish biting the crab, then another, until the crab is immobilized. Even so small a puffer has a beak

fully able to bite through a crab's shell. Examples of cooperative feeding, in which several individuals are able to get a meal where one could not, are rare in animals of such a supposedly low order of intelligence. The example of the thresher shark, given earlier, is the only other one that is known for fishes.

Similar Species: The northern puffer, *Spheroides maculatus,* is without bands on the tail but is otherwise like the southern puffer in size, habits, and appearance. It replaces the southern puffer to the north and is found as far north as Maine.

The sharp-nosed puffer, *Canthigaster rostratus,* is a tiny puffer of the coral reefs. It swims alone or with other small reef fishes and is altogether a very attractive and amusing fish as it bobs about among sea fans, gorgonians, and coral. It reaches only about 4 to 5 inches and is West Indian. It is a soft brown above and cream below, with dark lines radiating out from the eye. The tail fin is black on the upper and lower edges.

The Gulf puffer, *Spheroides annulatus,* is dark brown with light, curved streaks on its back. The back is covered with small dark spots as well. It reaches 1½ feet and is found north to San Diego in summer.

PORCUPINE FISHES: Family Diodontidae

These extremely bizarre derivatives of puffers do not have their beaks divided by a median suture and for this reason are named "Diodontidae" ("two-toothed"). Their habits are very similar to those of puffers, and they are able to inflate themselves to an equal degree. All of them are covered with stout spines which, in some species, are long enough to inflict painful injury. The profile, as well as the cross section, of these fishes is squarish, hence they are often referred to as "boxfishes." Their flesh is reputed to be poisonous especially in the tropics. Their distribution is world-wide in tropical seas.

PORCUPINE FISH: *Diodon hystrix*–*Color Plate 9*

Size: Averages over 1 foot. Up to 3 feet.

Distribution: Cosmopolitan in warm temperate and tropical seas.

Identification: The yellowish color and long, dangerous spines separate this fish from all others.

Habits: This fish is dangerous to handle. The spines are not poisonous, but they are erectile, very sharp, and capable of inflicting painful wounds. Their food, like that of puffers, consists mostly of shellfish and crustaceans. Some oriental people inflate the dried skins of these fishes and use them for lamps.

Similar Species: The spiny boxfish (swell toad), *Chilomycterus schoepfi,* has broad short spines and wavy dark markings on its yellowish body. It is very boxlike in shape. It reaches 10 inches and is the most northerly species of the family, ranging to Cape Cod from its normal West Indian home. A rare West Coast boxfish, *Chilomycterus affinis,* ranges north to San Pedro. It looks much like the East Coast form.

Mail-Cheeked Fishes: *Suborder Loricati*

This suborder includes several families in which spiny-headed bottom fishes predominate. All are voracious and carnivorous and usually have very stout dorsal and anal fin spines. All have a hard and usually spiny bone running

just beneath the eye on the cheek. This is one of the largest and most varied of all fish groups and its members are prominent in all seas from arctic to tropical, but they are most numerous and varied in cold temperate to arctic waters.

ROCKFISHES AND SCORPION FISHES: Family Scorpaenidae

This is one of the largest of fish families with 250 species. We shall consider this family as a series starting with the least spiny rockfishes, proceeding through the spiny rockfishes, and terminating with the most spiny and bizarre member of the family in our waters, the scorpion fish. The rockfishes are found in great profusion on our Pacific Coast, where they form the largest single group of fishes of over fifty species. Only the common, shallow-water species are included here.

Most rockfish get in quite deep waters. There is a decided tendency for rockfishes to become red in deep water and to remain on the bottom among rocks, where they are able to ambush the smaller fishes and invertebrates on which they feed. Most of them are ovoviviparous. The rockfishes look very much like moderate-sized basses, but the fin spines are stouter, and the heads are bonier, spinier, and rougher than in basses. The most advanced species in the family, the tropical scorpion fishes are extremely bizarrely marked, very spiny-headed fishes. They have lost the swim bladder in response to their exclusively bottom-living habits. Their habit of lying concealed in rocks and their excellent protective coloration make them difficult to see in reefs. Add to this the fact that their dorsal spines are virulently poisonous, and it is not so hard to see that here are formidable fishes, indeed.

Three species of the South Pacific and Indian Oceans, the black nohu, *Emmydrichthys*, the lionfish, *Pterois*, and above all the stonefish, *Synanceja*, are especially dangerous. Their dorsal spines convey a principally neurotoxic poison which causes the most extreme and excruciating pain, the result of which is often delirium and death. Scientifically trained persons have been "stung" by these fish and have accurately recorded the effects. Such tales are truly horrible. One of them is given by Smith (1951). He was pricked by two of the dorsal spines in his thumb. Seconds later he felt severe shooting pains up his arm to his neck. Using snake-bite treatment, he cut across the wounds, sucked them vigorously to remove what poison he could, and bound off the thumb from the rest of the body. Five minutes after the puncture, a pain of "an intensity never before experienced" spread over his hand. A very short time later, he was shaken with spasms and experienced "an insane desire to ease the mounting agony by rolling on the ground." This pain persisted for three and a half hours, after which time immersion in hot water was tried. "The effect was dramatic. The agony diminished rapidly to bearable proportions, and I returned to normal consciousness and unquenchable thirst." The thumb turned black that day and was without sensation. The next day large yellow blisters formed and, when punctured, drained for six days and were very painful. The swelling reached a maximum the third day after the wound. Penicillin was injected and probably saved his thumb by reducing the blistering and the possibility of infection. A month later, the black portions of the thumb fell away. Eighty days after the stab the hand was weak and the thumb still swollen and painful. The poison had a detrimental effect on Smith's health. Smith had previously been stung by an eagle ray and puts the stonefish "in a class by itself." It is fortunate that North American scorpion fishes are not as dangerous as the stonefish.

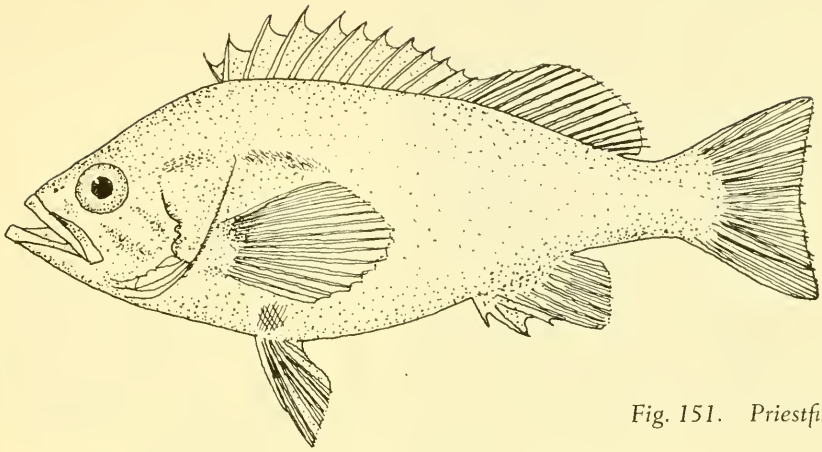


Fig. 151. Priestfish.

PRIESTFISH (BLACK ROCKFISH, ROCK COD, PÊCHE PRÊTRE): *Sebastodes mystinus*

Size: Up to 1½ feet.

Distribution: San Diego to Puget Sound. The most abundant rockfish around San Francisco and in the Juan de Fuca Strait.

Identification: Because this is one of the species that is least spiny, it looks much like a bass, but the head of the priestfish is bonier than that of a bass and there is a spiny preoperculum as well as a bony stay under the eye. This species has a blackish ground color mottled with dark and light blotches and has a white belly.

Habits: This is a voracious bottom fish very characteristic of rocky shallow waters. It eats small fishes and crustaceans. Large numbers of young, a quarter of an inch long, are born alive in the summertime.

Similar Species: The only Atlantic rockfish is the rosefish, *Sebastes marinus*, which is a rose-red in color and found in waters colder than 50° Fahrenheit, north of Maine in shallow waters and north of New Jersey in deeper waters. It reaches 2 feet in length.

The bocaccio, *Sebastodes paucispinis*, is dark brown above, orange to pink below, and generally flushed with red. It ranges from San Diego to British Columbia.

The green rockfish (yellowtail rockfish), *Sebastodes flavidus*, is a common shore form from San Francisco to San Diego. The body is grayish, becoming brown above and white below, with yellowish fins and tail.

RED ROCKFISH (TAMBOR): *Sebastodes ruberrimus*

Size: Largest of rockfish. Up to 2½ feet.

Distribution: San Diego to Puget Sound.

Identification: The head tends to be blunt with the top and sides covered with moderate spines. The color of this species is vermilion.

Habits: Like those of the priestfish.

Similar Species: The brown rockfish, *Sebastodes auriculata*, is the only rockfish that commonly enters bays. It is a blackish brown, mottled with light brown

and flushed with red. It ranges from Cape Mendocino south to Cedros Island. The Spanish flag, *Sebastodes rubrovinctus*, is very handsome with alternate vertical bands of red and rosy white. It is most common in southern California and ranges from Monterey to San Diego. It grows to 15 inches and keeps to moderately deep water.

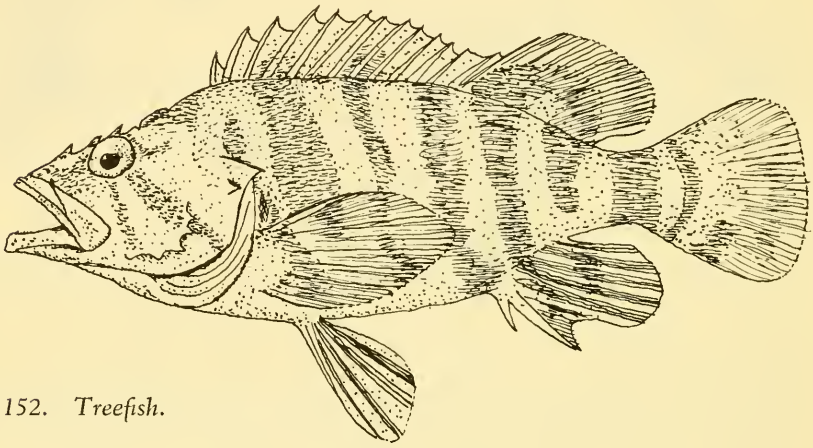


Fig. 152. Treefish.

TREEFISH: *Sebastodes serriceps*

Size: Up to 1 foot.

Distribution: Point Reyes to Cedros Island.

Identification: The body is stout and the head blunt and noticeably spiny. This species has an olivaceous body, becoming blackish above and yellowish below, with seven vertical black bands.

Habits: Like those of the priestfish. This fish has been observed to rest in holes in rocks with its belly up against the top of the hole.

Similar Species: The black and yellow rockfish, *Sebastodes chrysomelas*, is another small, heavy species which ranges from San Diego to Puget Sound. It has yellow and orange blotches on its dark brown body.

SCORPION FISH (LIONFISH): *Scorpaena grandicornis—Color Plate 3*

Size: Common at about 8 inches. Up to about 1 foot.

Distribution: West Indies to Florida. Straggles to Maine.

Identification: The head is very spiny and shaggy with fleshy protuberances. The dorsal spines are sharp and strong, and the first few of them are hollow and act like hypodermic needles. The poison glands are at the bases of the spines. The coloration is brownish to gray, mottled with many other colors, principally reds and yellows to form a concealing coloration. The color is rapidly adjusted to match the surroundings.

Habits: The concealing coloration and sluggish habits make this a difficult fish to spot. The danger of the spines has already been discussed. This is a voracious fish depending on ambush to get its small fish prey. It has been found with demoiselles in its stomach. It lies in rocks and reefs and, in the summer

ANSCOCHROME-BAHAMAS

Squids, among the speediest and most intelligent of marine invertebrates, are usually seen swimming in formation.

Sea slugs grow almost to football size, squirt dark, inky fluid when molested, and are one of the few animals that graze on large marine algae.

JOHN A. MOORE

ANSCOCHROME-BAHAMAS

Try to find the eyed platefish camouflaged against dead coral in the center of this picture.

Yellow goatfishes may either school densely or associate singly with mixed groups of miscellaneous reef fishes such as parrotfish and tang.

ANSCOCHROME-BAHAMAS

and fall, it lays balloonlike eggs in pairs. These float and are colorless. These floating eggs may be an aid to the dispersal of this sluggish fish. The young fall immediately to the bottom on hatching.

Similar Species: The "sculpin," *Scorpaena guttata,* is a West Coast form. It grows to 15 inches and ranges from Baja California to Monterey. There are many other similar species in all tropical seas.

SKILFISHES: Family Anoplopomidae

This is a small North Pacific family.

SKILFISH (SABLEFISH): *Anoplopoma fimbria*

Size: Up to 3 feet. Mostly much smaller.

Distribution: San Diego to the Aleutians.

Identification: The shape is long and slim and codlike. The spiny dorsal fin is like that of greenlings but the soft dorsal is shorter and is reflected by the anal in size and shape. There is a bony stay just under the skin below the eye. The color is slaty above and white below.

Habits: This is a common coast fish of the North Pacific. It is commonly sold in markets and is delicious smoked.

GREENLINGS: Family Hexagrammidae

This is another strange group of the North Pacific, the evolutionary place of which is not clear. The dorsal and anal fins are very long, and there are usually several lateral lines. The bony stay beneath the eye is present. The several species are all typical of inshore waters where there is kelp and rock. They are carnivorous on fishes and invertebrates.

KELP GREENLING (SEA TROUT, ROCK TROUT): *Hexagrammos decagrammus*

Size: Up to 1½ feet.

Weight: Up to 2 to 4 pounds.

Distribution: Point Conception north to Kodiak Island, Alaska.

Identification: The male is bluish with brown mottlings. The female is brownish with dark mottlings. There are five lateral lines on the sides and back.

Habits: This is a fish of the rocks and kelp beds, which eats crustaceans primarily.

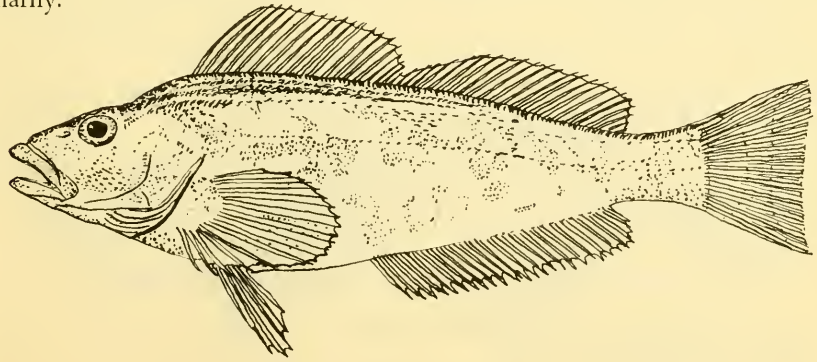


Fig. 153. Kelp greenling.

Similar Species: There are several other members of the genus *Hexagrammos* on the West Coast north of Monterey.

The cultus cod (ling cod), *Ophiodon elongatus,* is the largest of the greenlings, commonly reaching 3 feet and 30 pounds, and even growing to 70 pounds. It has a large mouth and strong teeth, indicating fish-eating habits. There is only one lateral line. The color varies with the habitat from dark brown to green, and there are green or yellow spots of small size over the body. The flesh is also green but is wholesome. It ranges from San Diego to southeastern Alaska.

The convict fish, *Oxylebius pictus,* is a small, very active wrasselike or gobylike greenling with a white to gray ground color crossed by six black bars. It is common in rocks and seaweed, ranges from San Diego to Puget Sound, and grows to 10 inches.

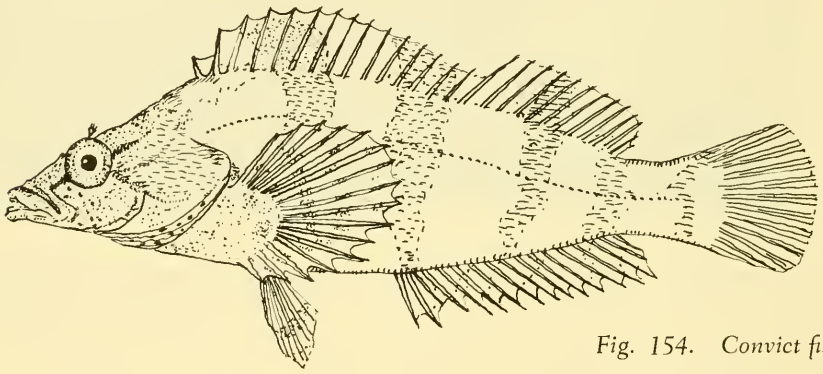


Fig. 154. Convict fish.

SCULPINS: Family Cottidae

There are a great number of species of these principally arctic fishes. None are found south of California or Virginia. They are bottom fishes which lie on rock bottoms, usually among seaweed, waiting for prey to come within their reach. The larger ones are fish-eaters mainly. The smaller ones are more omnivorous. Some of them look very much like the scorpion fishes with their large, fanlike pectoral fins and spiny heads. Sculpins are never completely scaled and are frequently quite pretty, especially the smaller species. These are sluggish fishes, which depend on concealment for protection as well as for getting food. As might be expected, the coloration varies to match the environment. If approached by a swimmer, they usually remain still until the last moment when they dart away with a sudden burst of energy and speed, but they never go very far. Frequently, the preoperculum with its spines will be erected in a threatening gesture. Most sculpins live in shallow water near shore or even in tidepools, but some get into very deep water. They range in size from a few inches to 2½ feet. A few species are found in fresh water and are very common there, for example, the miller's thumb, *Cottus.*

CABEZONE (MARBLED SCULPIN): *Scorpaenichthys marmoratus*

Size: The largest sculpin, reaching 2½ feet.
Weight: Reaching 25 pounds.
Distribution: British Columbia to San Diego.

Identification: The color varies. In eelgrass, the ground color is green, and in seaweed, it is brown. There are blotches and reticulations of green and brown on the body. The flesh is green. The shape is like that of the Greenland sculpin.

Habits: This is a fish of shallow waters, where it lies among rocks and vegetation. It ambushes fishes and crustaceans from its hiding place.

TIDEPOOL SCULPIN: *Clinocottus analis*

Size: Up to 7 inches.

Distribution: Monterey to southern California.

Identification: The color matches the environment. The shape is similar to that of the Greenland sculpin.

Habits: This and the very many similar small sculpins of shallow, rocky shores lie motionless to ambush all sorts of small animal prey. It lays its adhesive eggs on or under rocks and guards them until hatched.

GREENLAND SCULPIN: *Myoxocephalus scorpius*

Size: Up to 2 feet, but mostly much smaller.

Distribution: The arctic south to Cape Cod, and possibly to New York.

Identification: The separation of this fish from other sculpins is made on the technical basis of the possession of fourteen anal fin rays and only moderately long preopercular spines (see Breder, 1948). The color is mottled and variable.

Habits: This is a very voracious fish-eater, which may, at times, be omnivorous, eating any living thing it can swallow. It is sluggish and can even be touched while in the water. A grumbling sound may be uttered which is produced by muscles in the mouth and amplified by the throat cavity. Reddish, adhesive eggs are deposited in winter among rocks in a spongy mass. The male broods over them until they are hatched.

Similar Species: There are many abundant East Coast species. Among these is the sea raven, *Hemitripterus americanus*, which has the dorsal fin spines placed very high anteriorly. It can inflate to some extent like a puffer or a swell shark when handled. It ranges from Labrador to the Chesapeake, being rare south of Cape Cod. It is usually a dingy red to purplish, but some are yellow and are viewed by superstitious fishermen as omens of foul or fair fortune, depending on the locality (Breder, 1948). The sea raven grows to 2 feet but is rarely over 1 foot.

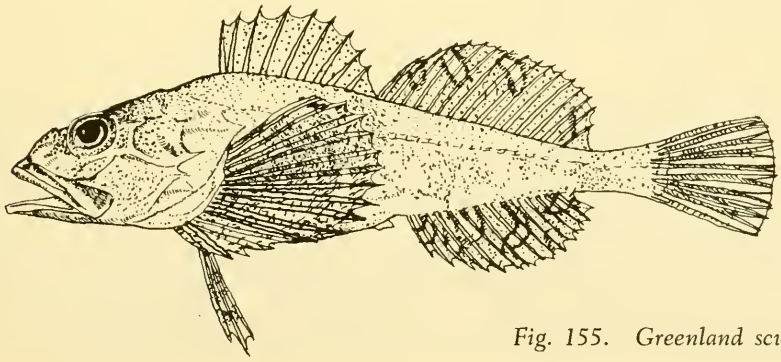


Fig. 155. Greenland sculpin.

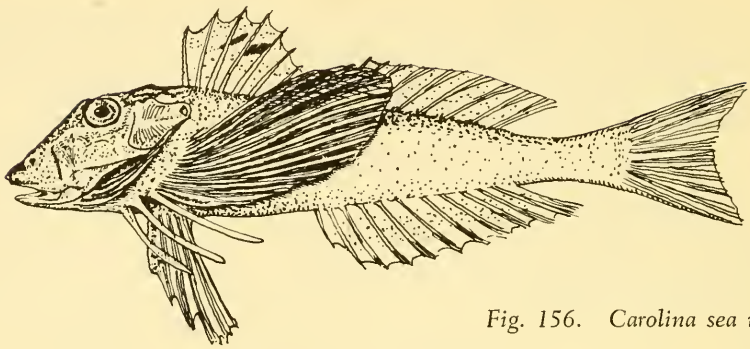


Fig. 156. Carolina sea robin.

Sea Robins: *Suborder Craniomi*

This suborder is clearly a derivative of the mail-checked fishes. The suborbital bony stay is even better developed in sea robins than in mail-checked fishes, but sea robins add another characteristic that sets them apart. The pectoral fin is divided into an upper winglike part and a lower part of several independently movable rays. With these pectorals and the pelvics, these fishes can perform an amazing variety of functions. The large pectorals serve as oars (or improbably as wings for short flights out of water in the most advanced species). The finger-like pectorals can turn stones, prod about for food, and act altogether like hands. The pelvics (and lower pectorals as well) serve as legs on which the fish walks slowly and stealthily when it is on the bottom. Sea robins are principally crustacean- and invertebrate-eaters and are found in most temperate and tropical seas. The colors are often quite beautiful, with red predominating in the tropics.

SEA ROBINS: Family Triglidae

The pectoral is large but not developed into a large wing in these fishes. The tropical species are usually found in fairly deep water. Some of these are very bizarre, with long chin barbels and pointed snouts.

CAROLINA SEA ROBIN: *Prionotus carolinus*

Size: Averages 1 foot. Up to 1½ feet.

Weight: Up to 2 pounds.

Distribution: Bay of Fundy to the Carolinas.

Identification: This species is not strongly marked except for a few blotches. The chin is black.

Habits: This is mainly a bottom fish which may be found creeping about over sand. It moves to deep water in the cold months. It would be of great scientific interest to photograph this fish in its natural habitat and to make careful observations of the use of the fins particularly. This fish lays floating, nonadhesive eggs in the summer.

Similar Species: There are many species in temperate and tropical waters. Most of the latter are of deep-water habitat. The southern sea robin, *Prionotus tribulus*, is a very common Gulf of Mexico and South Atlantic shallow-water form. It has three or four dark, blotchy, vertical bars on a yellow-tan ground color.

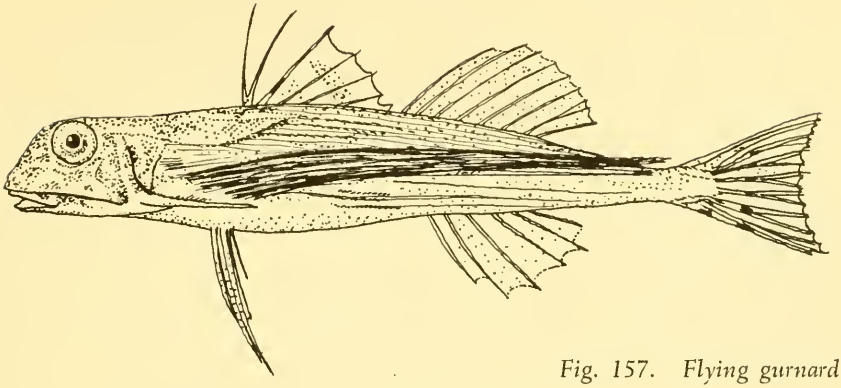


Fig. 157. Flying gurnard.

FLYING GURNARDS: Family Dactylopteridae

These fishes have very large, winglike pectorals which, when folded back, reach nearly to the tail. They are of tropical distribution. The coloration varies with the surroundings. The ground color is usually olive or brownish, and the pectoral fins are mottled.

FLYING GURNARD: *Dactylopterus volitans*

Size: Up to 1 foot.

Distribution: West Indies to Cape Cod. Rare to the north.

Identification: Same as for family.

Habits: This is, as Beebe and Tee-Van (1933) say, the most versatile of fishes. It can walk, use its fins as hands, feet, or oars, and, of course, swim. The special adaptations of this suborder reach their epitome here. Otherwise, the habits are similar to the sea robins. Beebe and Tee-Van (1933) say that they are able to glide. Breder (1948) adds that the flight is not as long as that of flying fishes. Longley and Hildebrand (1941) doubt that this fish can fly, since "the pectorals are so thin and flexible that the fin droops almost of its own weight." They can walk on their pelvic fins better than the sea robins can and are most often seen propped up or moving on these fins over sandy bottoms in shallow water. The activities of gurnards may deserve even more careful observation in their natural habitat than those of the sea robins.

Gobies: *Suborder Goboidei*

This is a distinct group of unclear relationships. Typical gobies have no lateral line and have the ventral fins united into a sucking disc. The spiny and soft dorsal fins are typically distinct, and the soft dorsal and anal fin reflect each other in size and shape. In all of these respects, gobies differ from the very similar blennies, but the best way to tell gobies and blennies apart is not, in most cases, anatomical. Gobies are much less eellike in shape than blennies and their movements are likewise much less serpentine. They are frequently seen propped up, or adhering by their ventral fins, on sand and mud flats, rocks, reefs, or in tidepools, but their movement is very quick and of a darting nature,

almost jerky in contrast to the blenny's quick, but more flowing, wavelike motions. Gobies cannot walk on their ventral fins as blennies can.

This is as confused a group regarding its names as one is liable to meet. There are hordes of species found in tropical and temperate zones the world over, both in salt and fresh waters. Furthermore, males and females not only differ from each other in colorations, but also change their colors widely in response to emotional as well as environmental stimuli. In spite of these difficulties, these are among the most rewarding of fishes to study. They are small, unafraid, common in shallow water, can be approached closely, and have remarkable courtship and breeding behavior. In all these respects they parallel blennies ecologically. Several of them show a marked tendency to become semiterrestrial. They can trap water in their gill chambers by means of a membrane and thus they can live for several hours out of water. Fishermen are able to keep some species alive for a week stored in damp seaweed.

Gobies "home" to a particular spot and have good memories for their home territory.

If the swimmer remains stationary in the presence of gobies, they will soon grow accustomed to him and may even use parts of his body as vantage points.

Gobies have elaborate courtships. The male selects a hole in the reef or rocks or a shell or even builds a house of mud and sand. Then he entices a female to his lair by means of peacocklike displays of fins and movements. The female lays eggs and departs. The male may then fickly entice one or more additional females to lay eggs in the same fashion. Then the male guards his precious horde, being extremely intolerant of intruders and not eating until the eggs are hatched.

These pert, lively, somewhat irascible little fishes are rarely over 6 inches in length. One of them matures at half an inch. The largest reaches 2 feet. Most are able to survive in very stagnant water. They are fiercely carnivorous on small invertebrates and range throughout tropical and warm temperate seas.

GOBIES: Family Gobiidae

MAPO (SHEEP'S HEAD MOLLY MILLER): *Bathygobius soporator—Color Plate 3*

Size: Up to 6 inches. Mostly much smaller.

Distribution: West Indies north to Cape Hatteras. Western coast of Mexico.

Identification: The five pectoral rays on the dorsal side of the pectoral fin separate this fish from all other gobies. The color is variable but is usually pale gray to green or brown with mottlings or vertical bars. When over light bottoms or when alarmed, the fish assumes a very light phase.

Habits: This fish is very common in shallow waters and tidepools throughout its range. It is a typical goby in size, shape, and habits. This is the species that has been the most studied of the gobies. Aronson (1951) made a fascinating study of its homing and leaping behavior. He noticed that mapos frequently leap unerringly from tidepool to tidepool, even though they could not possibly see where they were going to land due to the steep sides of the tidepool from which they leapt. The leap is accomplished by an extremely rapid straightening of the tail. Aronson says that this accurate jumping does not result from trial and error learning, but "it is suggested that these gobies swim over the tidepools at high

tide and acquire an effective memory of the general features of the topography of a limited area around the home pool which they are able to utilize when locked in their pools at low tide."

Tavolga (1954) has studied the complex breeding behavior of this fish, which seems to be fairly typical of gobies and also of blennies. The male fishes are vigorous in their protection of a home territory, which is usually a small area surrounding some crevice or hole in the rocks. They may even choose a shell or tin can as a home and can be captured by placing empty cans in waters where gobies are found. Usually they show colors that somewhat match their environment, but at times of fighting between males or mating, dark, background-contrasting colors are put on. Fighting males also show "throat-puffing, gasping, quivering, butting, and biting movements." After a site is chosen, it is cleaned by the male. He then approaches the female with a vibrating motion of the fins and tail, and both male and female change colors with their emotional state. The female enters the nest cavity twelve to twenty-four hours before laying her 15,000 to 18,000 eggs, a feat that takes three to nine hours. The female departs, and the male guards and fans the eggs. Females can lays eggs every seven to sixteen days. With a fall in water temperature, the male will brush the eggs vigorously to induce hatching five to seven days after the eggs were laid. Tavolga says, ". . . the natural temperature stimulus may be the inundation of the tidepool by cooler water by a rising tide. This would insure a wider dispersal of the pelagic larvae by the tidal water current."

Similar Species: Other small gobies are found north to Cape Cod. On the West Coast there are numerous similar species found south of Vancouver. Most West Coast forms are small (up to 3 inches) and are most common in bays and on mud flats.

SLEEPER: *Dormitator maculatus*

Size: The largest goby, up to possibly 2 feet. Mostly under a foot.

Distribution: West Indies to South Carolina.

Identification: The mulletlike shape, large size, and gobylike fin pattern identify it. Its colors are extremely varied.

Habits: The sleeper can live in salt, brackish, and fresh waters. Like the killies, it can stand a wide range of pollutions and temperatures, so it makes a good aquarium pet. In spite of the large size, its habits are like those of the smaller gobies.

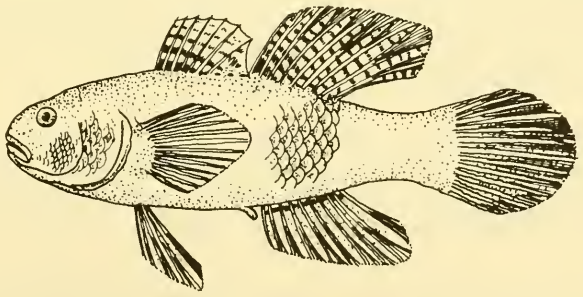


Fig. 158. Sleeper.

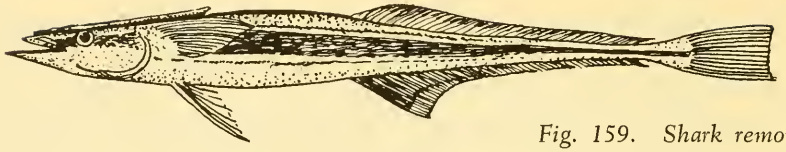


Fig. 159. Shark remora.

Remoras: *Suborder Discocephali* ("*disc head*")

These remarkable, elongate fishes are easily recognized. The top of the head bears a laminated disc by which means these fishes are able to attach strongly to sharks, rays, large fishes such as spearfishes and barracudas, sea turtles, or other large animals for the purpose of securing a ride. They are not parasitic, but just hitchhikers which share in the scraps left by large predators. They are swift swimmers in their own right (as they have to be able to pick up their rides) but probably cannot travel long distances by themselves. They are rarely seen unattached. The strength of this sucker is remarkable. In order to capture turtles, West Indian natives pay remoras out on a line and allow them to attach to the turtles (Beebe and Tee-Van, 1933). Most of the species are cosmopolitan in warm seas and all are carnivorous.

REMORAS: Family Echeneidae

SHARK REMORA (SUCKFISH, PEGADOR): *Echeneis naucrates*

Size: Averages 18 inches. Up to 3 feet.
Weight: Up to 2 pounds or more.
Distribution: Cosmopolitan in warm seas.
Identification: The color is gray with a wide, longitudinal black band.
Habits: This is the largest of the remoras. It is most often seen attached to large sharks or other large fishes. Other smaller species attach to smaller fishes for free transport.

Trachinoids: *Suborder Trachninoidei*

This group contains a large assemblage of fishes which defy exact definition. Just as the species of the order Mesichthys are transitional from primitive bony fishes to the spiny-rayed fishes, the trachinoids are transitional from spiny-rayed fishes, which have ventral fins placed in the thoracic (chest) position under the pectoral fins, to the fishes with the ventral fins placed in the jugular (throat) position. None of the families have many species.

BLANQUILLOS: Family Malacanthidae

These are mostly tropical fishes of world-wide distribution. A few are found in temperate zones. They are elongate and compressed with long, low dorsal and anal fins. The colors are silvery or whitish with overtones of yellow and green.

SANDFISH (WHITEY, BLANQUILLO): *Malacanthus plumieri*

Size: Averages about 1 foot. Up to 2 feet.

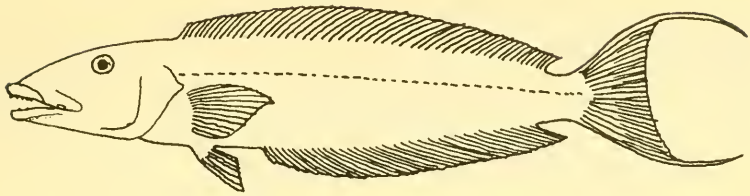


Fig. 160. Sandfish.

Distribution: West Indies to Florida.

Identification: This is an elongate, almost eellike fish. The colors are delicate and quite beautiful with whitish and pale yellow predominating. There are canines in the front of the jaws.

Habits: This fish is quite common and is most often seen wending its way in a rather eellike fashion in and out of holes of reefs near sandy places and gorgonian beds. It is a feeder on invertebrates.

Similar Species: The ocean whitefish, *Caulolatilus princeps,* is found inshore among rocks from Monterey to the tropics. It grows to over 3 feet. In shape it is like a deep-bodied sandfish, and it has a rather small mouth.

The tilefish, *Lopholatilus chamaeleonticeps,* is an offshore fish which feeds in the deep water near the outer continental shelf. Its ground color is whitish; numerous blue and yellow spots cover the body. Ahead of the soft dorsal fin on the head is a fleshy, erect tab. It ranges from Maine to the Chesapeake and averages 3 feet and 30 pounds.

ELECTRIC STARGAZERS: Family Uranoscopidae

This is an odd family, widely distributed in warm seas.

NORTHERN STARGAZER: *Astroscopus guttatus*

Size: Up to a little over 1 foot.

Distribution: New York to Cape Hatteras.

Identification: The chunky body with vertical mouth and eyes on the top of the head identifies it.

Habits: This fish is much like the anglers in habit. It lies buried in sand with only the eyes and mouth protruding. A little filament in the mouth looks like a worm and is wiggled to lure small fish which are then snapped up in the large jaws. These fishes lay floating eggs in the summer. The stargazer can deliver a noticeable electric shock. The electric organs are formed by modified optic nerves.

The habit of lying buried in sand presents a difficulty in breathing, since water entering the mouth would bring sand with it. This problem has been solved in this fish by passing water in and out through its nostrils, which are connected to the throat cavity by a tube. These are the only fishes in which the nostrils are not a blind pouch used for smelling only.

Similar Species: The southern stargazer, *Astroscopus y-graecum,* replaces the northern species south of Cape Hatteras and is found over the West Indies.

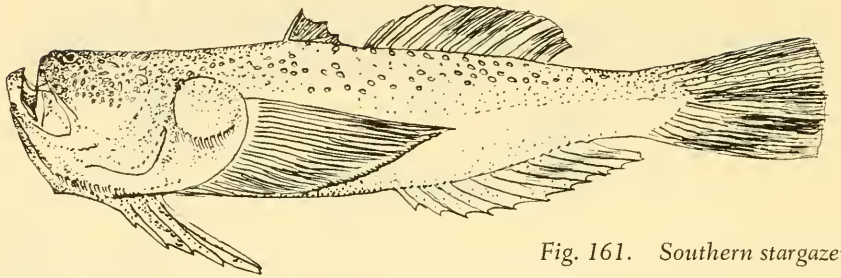


Fig. 161. Southern stargazer.

Jugular Fishes: *Suborders Haplodoci, Xenopterygi, Blennoidei, Ophidioidei, Anacanthini*

Several suborders, listed above, all have one feature in common, the jugular (throat) position of the ventral fins. This position is more concerned with the internal bony support of these fins than with their outward appearance, so it cannot invariably be used as a field character. These suborders are so different, however, in many other respects that they cannot be included in any one suborder (Jugulares) as they were several years ago. Nowadays, the term "jugular fish" is most often used to designate the last order mentioned, the Anacanthini, including the cods and lings. Nevertheless, the general trend of the bony fishes to move the ventral fins forward reaches its culmination in these suborders. The authors believe that these suborders should be grouped under the common name of "jugular fishes" without any single suborder name being set aside for them. Several of the jugular suborders show a tendency to be northern in distribution and somewhat degenerate in form.

Toadfishes: *Suborder Haplodoci*

These are sculpinlike, bottom fishes which lie concealed or buried on sandy, weedy, or rocky bottoms. They may be distinguished by the great reduction of the spiny dorsal fin and by the long, soft anal fin. There is one family of temperate to tropical distribution in North and South America. Some South American species possess poisonous spines.

TOADFISHES: Family Batrachoididae

TOADFISH: *Opsanus tau*

Size: Averages 8 to 10 inches. Exceptionally to 15 inches.

Weight: Exceptionally to 2 pounds.

Distribution: Maine to the West Indies. Most common from Cape Cod to Cape Hatteras.

Identification: This fish has no scales and appears to be almost all head. It is a mottled brown and yellow-brown. From the lower lip are hung fleshy tabs, which probably serve to break the outline of the menacing jaws.

Habits: This is a sluggish fish and is very common hiding among rocks, weeds, and rubbish, from which vantage it darts quickly out at its prey. Gill (1907) states that toadfishes eat a wide variety of animal food, and it is the authors'

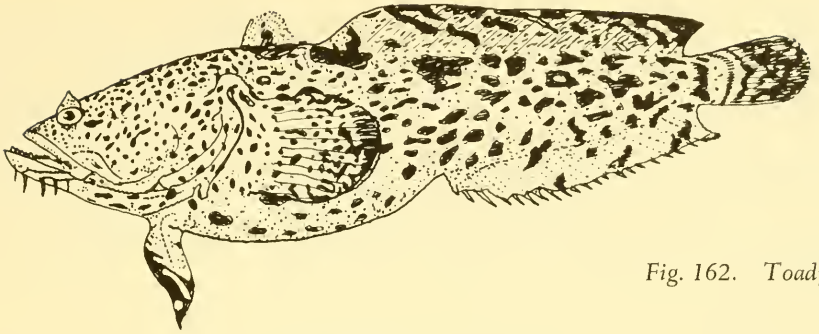


Fig. 162. Toadfish.

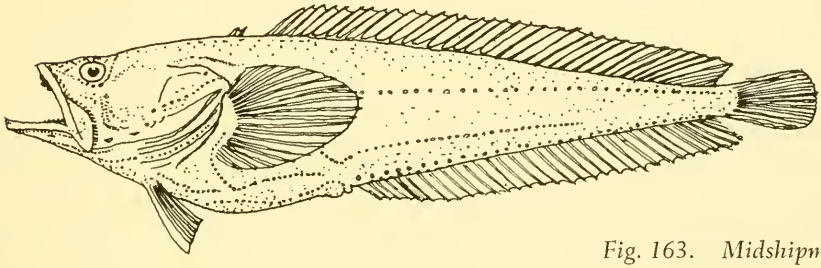


Fig. 163. Midshipman.

experience that just about anything of proper size will be swallowed. This pugnacious fish will not usually retreat before the underwater swimmer, but will threaten by opening its mouth and it will snap quite freely at fingers thrust its way, being able to give a painful bite with its powerful jaws. Toadfishes may be easily captured by thrusting a blunt stick into their jaws, whereupon the fish takes a firm hold and may then be netted. When so disturbed, a toadlike croak is usually uttered. The breeding season is late spring or early summer. The adhesive eggs are fastened to a stone, tin can, or similar crevice and are guarded by the male, whose natural pugnacity is magnified at that time.

MIDSHIPMAN (BAGRE SAPO, SINGING FISH): *Porichthys porosissimus*

Size: Up to about 8 inches.

Distribution: South Carolina to Argentina. Fairly common in the Gulf of Mexico.

Identification: The shape is distinctive. There are rows of silvery, dark-outlined pores on the sides and head.

Habits: When captured, this fish makes a peculiar vibratory, humming sound with its air bladder, which accounts for the name "singing fish." In habits, it is much like the toadfish, but it is not as pugnacious.

Similar Species: The California singing fish, *Porichthys notatus*, is very similar. It is found off the coasts of California.

Cling Fishes: *Suborder Xenopterygi*

These are extremely tadpolelike fishes. Briggs (1955) has monographed them, stating that this suborder of odd fishes is probably most closely allied to the

Haplodoci (toadfishes). They are scaleless, covered with a thick coat of mucus (probably a protective device which renders them very slippery), and have the ventral fins united into a sucking disc, allowing them to maintain their position adhered to rocks in streams or in shallow seas. Their flat shape offers little resistance to currents or waves, so they are often found in places where the water is quite rough. There are less than a hundred species, of world-wide distribution in warm seas. They are usually not numerous and are hard to see. One odd, elongate clingfish of the Indo-Pacific hides habitually among the spines of a sea urchin. In size they range from less than an inch to 10 inches. There is only one family.

CLINGFISHES: Family Gobeisocidae

CLINGFISH: *Gobiesox strumosus*

Size: Up to 4 inches or more.

Distribution: Chesapeake Bay to the West Indies.

Identification: Same as for the suborder. The color is a dull monotone of dark gray to brown, as it is in many clingfishes.

Habits: Clingfishes spend most of their time adhering to rocks or other hard items of substrata. They eat crustaceans and other invertebrates, and probably some plant matter as well.

Similar Species: This genus is confined to the New World, four species on the Atlantic side and twenty-two species on the Pacific. All are very similar and range throughout the American warm temperate and tropical zones.

Blennoid Fishes: *Suborder Blennoidei*

The three families of blennoid fishes are largely of arctic and tropical seas, being curiously scarce in the temperate zone. Most are small, and there is a definite tendency for them to become elongate and eellike, and to adopt burrowing habits. The dorsal and anal fins are long and continuous. The ventral fins are slender, not united in a sucking disc, and are placed far forward. Some blennoids even lack ventral fins.

BLENNIES: Family Blennidae

These are small arctic or tropical fishes which are sometimes scaleless and eellike (particularly the arctic species). Much that has been said of the tropical, shallow-water gobies also applies to the tropical, shallow-water blennies, of which there is a huge array of prettily colored species with fascinating habits. They resemble gobies in being common in shallow water in tidepools, coral reefs, and rocks, and in their habit of appraising their surroundings from a position propped up on their ventral fins. They also show resemblance to gobies in their equally as fascinating social and breeding behavior, their tendency toward semiterrestrialism, their alertness, and lack of fear, and their accessibility for study by the swimmer. They differ from gobies in their more flowing serpentine movements and shape, their slender ventral fins on which they prop themselves up, and their continuous dorsal fin. The ventral fins are used like feet in walking or even like hands in manipulating objects. The authors have had blennies fearlessly crawl over their bodies using these ventral fins.

Like the gobies, blennies can live a very long time out of water, providing they are kept moist. Some of them even have the habit of sun-bathing out of water on rocks or mud flats. When approached, they will leap back into the water with a flick of their tails. In or out of water they have excellent eyesight and hunt their invertebrate food by sight. Their large eyes and active movements make them appear to be rather intelligent. It should not be hard to test their intelligence in their natural habitat, for blennies are quite fearless.

Their colors are quite often extremely attractive, being satiny and smooth and among the prettiest found in fishes. These colors are quite variable, matching the environment or correlated with the excitement of courtship. The breeding behavior is much like that of gobies. The male selects and cleans a hole or cavity in rocks or weeds for a nesting site. He then entices a female to his lair by raising and lowering himself on his ventral fins or by brushing at her and even bumping her with his nose. De Latil (1955) says that occasionally the female becomes aroused first and reverses the procedure by enticing the male. After egg-laying, the male guards the nest, being extremely intolerant of intruders, especially other males of the same species. He fans the eggs until they hatch and does not eat during the incubation period. It is amusing to watch a male blenny's reaction to a mirror. He can be driven to an extremely excited, furious state, especially if the mirror is presented between him and his nest. Like gobies, blennies may be caught by placing empty tin cans in areas where they are found.

This is one of the largest and most confusing of fish families. There are five hundred species ranging in size from an inch or two up to almost 2 feet and distributed over the entire world, especially in the tropics or the arctic. These species seem to be almost as confused among scientists as among laymen. The various adaptive types of blennies are reviewed here, but no attempt is made to be comprehensive as to species or even genera.

KELP BLENNY: *Heterostichus rostratus*

Size: The largest blenny. Up to 2 feet.

Distribution: San Francisco to Baja California.

Identification: The head is long and low in contrast to most blennies. The color varies with environment; it is brown in seaweed and barred with green in eelgrass.

Habits: This is a fish of the rocky, kelp- or seaweed-covered shores. Just as the largest sea horse is found among the largest seaweeds, the kelps, it is probably no coincidence that the largest blenny is also found in that giant forest. Strings of eggs are bound around seaweeds and guarded by the male. The habits are not significantly different from those of smaller, tropical blennies.

MOLLY MILLER: *Blennius cristatus*

Size: Up to 4 inches.

Distribution: Florida to Brazil.

Identification: The comb on the top of the head identifies this small species. The colors are variable; they are often in a series of bands. The shape is similar to the blenny shown on *Color Plate* 3.

Habits: This is one of the typical, small, shallow-water or tidepool species that are mostly of tropical seas, though some do get into warm temperate waters. These species are very hard to separate from each other. Some of these are semi-

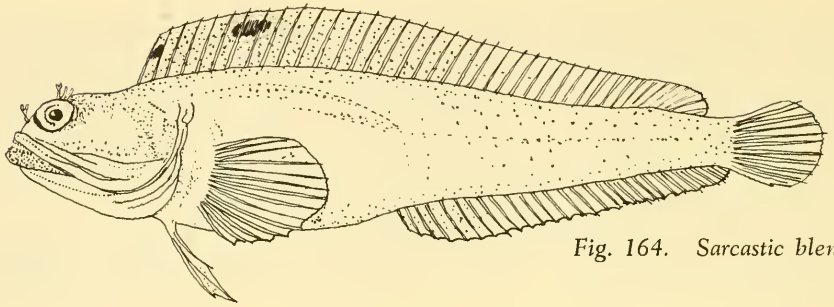


Fig. 164. Sarcastic blenny.

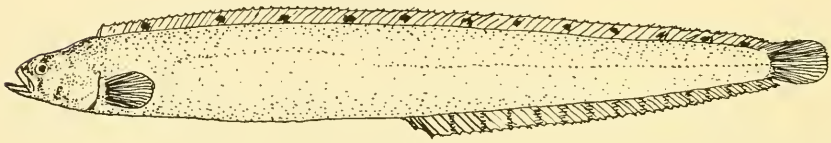


Fig. 165. Rock eel.

terrestrial in habits, sun-bathing on rocks or mud flats. All are alert, big-eyed, and have the typical blenny stance, propped up on the slim ventrals, which are also used in "walking."

SARCASTIC BLENNY: *Pterognathus satiricus*

Size: Up to 9 inches.

Distribution: Monterey Bay to San Diego.

Identification: The large mouth caused by the extreme elongation of the maxillary, or upper jawbone, identifies this odd blenny.

Habits: The habits are like those of other small blennies.

ROCK EEL (GUNNEL): *Pholis gunellus*

Size: Up to 12 inches, but mostly much smaller.

Distribution: Arctic south to Cape Cod, straggling to New Jersey.

Identification: The long, eellike shape and the tail fin which is separate from the dorsal and anal fins identify the various species of rock eels. The ventral fins are extremely small. The color varies from greenish brown to red.

Habits: These eellike blennies are typical of arctic and cold temperate members of this family. This shape is adapted to a secretive life on rocky shores. One of the authors found a very plentiful similar species among rocks and stones in the tidal zone on southeastern Alaskan shores. Almost every stone that was turned yielded one or more. Rock eels are exceptionally slippery and agile, however, and are more difficult to catch than they would seem to be at first sight. They feed mostly on small invertebrates and lay eggs in a cluster in their rocky home. Breder (1948) states that one of the parents apparently coils itself around the incubating eggs.

Similar Species: There are several West Coast species found south to California. Elongate, eellike blennies of several other kinds are also found in northern waters, but very little is known about them.

WRY MOUTHS: Family Cryptocanthodidae

These are arctic and north temperate fishes which are very eellike and which lack both ventral fins and lateral line. The tail fin is joined to the dorsal and anal fins. The gill openings are large, a characteristic which separates wry mouths from true eels.

WRY MOUTH: *Cryptocanthodes maculatus*

Size: Up to 3 feet.
Distribution: South to Cape Cod, straggling to New York.
Identification: Same as for the family.
Habits: This is a heavy-jawed fish which feeds on the larger invertebrates and fishes, which it probably ambushes. It lives at the bottom, particularly in mud, in branching burrows.

WOLF FISHES: Family Anarhichodidae

These are the largest blennoid fishes. They are of northern distribution in the Atlantic and Pacific and of eellike appearance. The jaws are large, extremely powerful, and armed with an impressive array of teeth, pointed in the front of the mouth and molarlike in the rear. There are no ventral fins. These are extremely voracious fishes which can be very dangerous to handle.

COMMON WOLF FISH: *Anarhichas lupus*

Size: Up to 5 feet.
Weight: Up to 30 pounds.
Distribution: South to Cape Cod, straggling to New Jersey.
Identification: The body is crossed by nine to twelve dark bars.

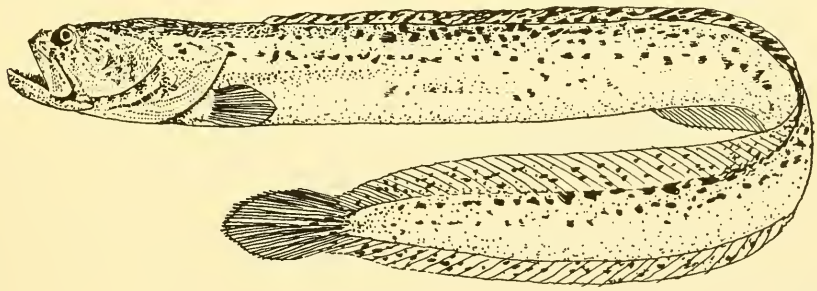


Fig. 166. Wry mouth.

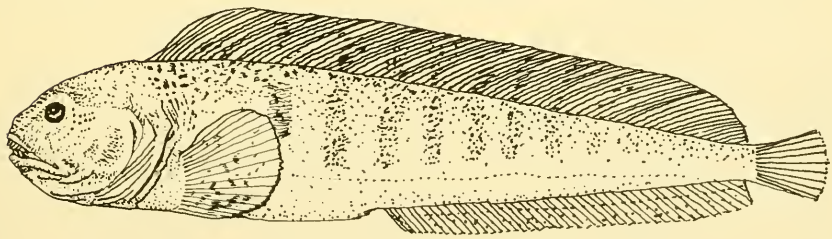


Fig. 167. Common wolf fish.

Habits: The food, as would be indicated by the very heavy, powerful molars, consists mostly of hard-shelled molluscs and crustaceans. Like many other northern fishes, its spawning season is in winter.

This fish is pugnacious, and care should be taken in approaching it under water. Wolf fishes are mostly sluggish and nocturnal, but don't be fooled by this. They will bite, and very painfully, too.

Similar Species: Several other species are found in the Atlantic. On the Pacific Coast wolf fishes are found south to Monterey, California, to which point the wolf eel, *Anarhichas ocellatus*, ranges.

Ophidioids: *Suborder Ophidioidei*

These are degenerate derivatives of the blennoid fishes. There are no spines in any fin except a few in the dorsal. There is usually no definable tail fin, the dorsal and anal fins, with few exceptions, being continuous with it, with no breaks. In this feature, they parallel the true eels but are unlike true eels in possessing large gill openings. Several of them are very similar to the eellike blennies. The distribution of the several families is world-wide from the tropics to the arctic. All of these fishes are bottom-living. They show a tendency toward burrowing habits.

EELPOUTS: Family Zoarcidae

The ventral fins of these fishes are small and placed at the throat. They much resemble the eellike blennies in habits and appearance but are larger. They are found in both the Atlantic and Pacific in the arctic and north temperate zones. Some eelpouts give birth to living young.

SHORE EELPOUT: *Zoarces anguillaris*

Size: Up to 3½ feet. Uncommon over 2½ feet.

Weight: Up to 12 pounds.

Distribution: North temperate waters south to Delaware.

Identification: This is one of the few ophidioids which has discontinuous dorsal and anal fins.

Habits: The movements of this fish are snakelike. It lives among stones in the tidal zone or in shallow water, and in the summer it moves to cooler waters offshore. It eats large invertebrates and fishes.

Similar Species: Several West Coast species are found from the arctic south to southern California.

CUSK EELS: Family Ophidiidae

These are very similar to eelpouts, but they are usually small and range in the deeper waters of warm or tropical seas. The ventral fins are very far forward, appearing to be two long barbels under the chin, and are used as tactile organs to find food. Though there are several species found the world over, they are apparently not common anywhere—but this may only be a consequence of their secretive habits, which prevent them from being observed. Most species reach a maximum size of 1 foot, but one species of South Africa reaches 5 feet.

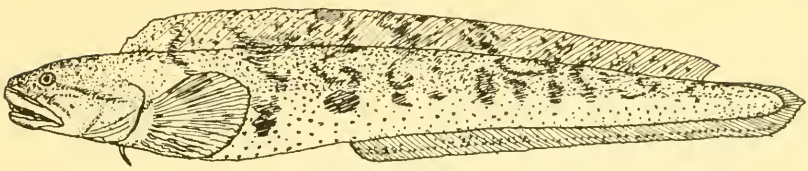


Fig. 168. Shore eelpout.

Fig. 169. Northern slippery dick.

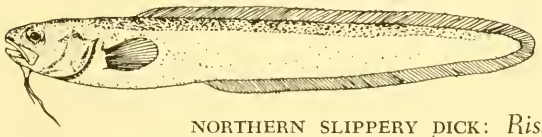
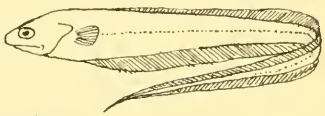


Fig. 170. Pearlfish.



NORTHERN SLIPPERY DICK: *Rissola marginata*

Size: Up to 6 inches.

Distribution: New York to the Gulf of Mexico.

Identification: Same as for the family.

Habits: This fish is a burrower in shallow sandy shores. It probably eats invertebrates.

Similar Species: Several Atlantic species are found in the West Indies and north in warm temperate waters. On the West Coast several species range north to southern California. Herald (1953) reports that a spotted cusk eel, *Otophidium taylori*, adapted to captivity quickly. He says that this fish adopts a position standing on its tail on the tank bottom and customarily enters hiding places tail first as does the pearlfish.

PEARLFISHES: Family Fierasferidae

These are among the most specialized and interesting of fishes because of their habit of living nonparasitically in the mantle cavities of oysters, where they are sometimes trapped and covered with mother of pearl by their host, or, more often, in the cloaca of a sea cucumber, especially the bêche-de-mer. These are small fishes with large heads and a body that tapers off to a point behind. There are several species of the single genus in tropical seas. They are pearly in color and semitransparent.

PEARLFISH: *Fierasfer affinis*

Size: Up to 5 inches. Usually smaller.

Distribution: Florida to the West Indies.

Identification: Same as for the family.

Habits: This fish lives symbiotically in the cloaca of sea cucumbers, or in the shells of molluscs. It is not a parasite, but merely uses these retreats as a home, as a blenny might use a tin can or rock crevice. At night, they wander from these homes to search out their invertebrate food. They may be captured by collecting large sea cucumbers and examining them with a probe or cutting them open. Linton (1907) placed a pearlfish in a dish with a large, living sea cucumber and observed that the fish hunted around the dish aimlessly until contact with the sea cucumber was made, then forced its way, tail-first, into the cloaca, a feat taking about thirty seconds.

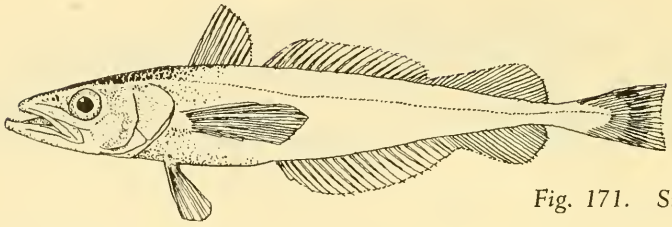


Fig. 171. Silver hake.

Hakes and Cods: *Suborder Anacanthini*

These are mostly northern and deep-sea fishes. There are no spines in any of the fins. The vertical fins have been derived from a single, continuous dorsal-caudal-anal fin by breaking this fin into sections. Typically, these sections appear as multiple dorsal and anal fins with a single caudal fin. However, in some eel-like forms such as cusks, there are only single dorsal and anal fins. The better-known members of this suborder are large, voracious fishes, which tend toward bottom feeding.

HAKES: Family Merluccidae

This is a small group of the North Atlantic, North Pacific, and Chilean waters. All the species are extremely voracious, large-mouthed feeders on fishes and larger invertebrates, such as squids and large crustaceans. There are no barbels on the chin. The dorsal fin is divided in two parts (the second part is long and appears to be divided); the anal fin is single. The build is pikelike, and the color is a dull silver-tan.

SILVER HAKE (WHITING): *Merluccius bilinearis*

Size: Averages a little over 1 foot. Up to 2 feet.

Weight: Averages a little over 1 pound.

Distribution: From the Grand Banks off Newfoundland to the Bahamas, in deep water.

Identification: Same as for the family.

Habits: This is a schooling dish, most common over sand or pebble bottoms. It comes nearest to shore in autumn during the breeding season, when it lays several thousand pelagic, nonadhesive eggs. It ranges through a great depth of water from the surface to 1,500 feet, in other words, through the whole of the lighted zone of the sea.

Similar Species: The California hake, *Merluccius productus,* is found from the Gulf of California to Puget Sound. It is abundant in water of moderate depth and reaches a length of 3 feet.

CODS: Family Gadidae

These fishes of the North Atlantic and North Pacific seas have a single chin barbel, a large mouth, and feed mostly near the bottom on a wide variety of animal foods. They are all extremely prolific, laying pelagic, nonadhesive eggs, sometimes literally by the millions. Most of the species travel and feed in very large roving schools and are the object of important fisheries. Some of the deep-water forms have single dorsal and anal fins, but the well-known species have

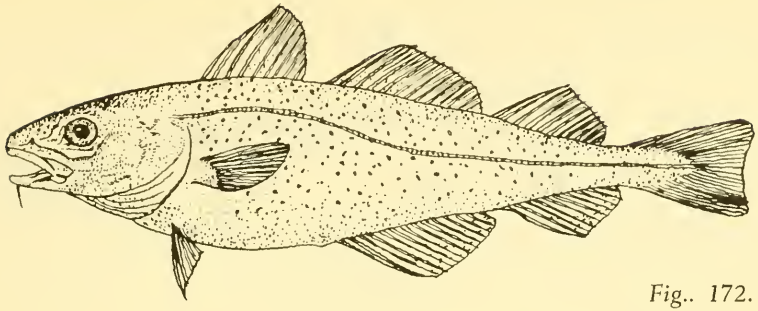


Fig.. 172. Cod.

three dorsals and two anals. There is a tendency for these fishes to keep to moderately deep water.

COD: *Gadus callarias*

Weight: Commonly to 25 pounds. Rarely from 60 to 70 pounds. Known to reach 200 pounds.

Distribution: Greenland to Cape Hatteras. Very abundant from Newfoundland to Cape Cod the year round. Goes offshore in warm months to the south of its range.

Identification: Three dorsal fins and two anal fins, all spineless. The lateral line is paler than the rest of the brownish body. (Small cods are reddish and are called "rock cod.") The tail fin is squared off.

Habits: This exceedingly voracious fish travels in huge roving schools and feeds on small fishes and invertebrates, mostly over rocky or sandy bottoms. Cods come inshore in shallow water but also range in waters as deep as 1,500 feet. This fish is immensely prolific. A large female of 70 pounds has been estimated to produce about 9 million eggs, only about one seventieth of which ever reach the hatching stage, so harsh are the environmental forces of destruction of pelagic eggs. Spawning is probably indiscriminate, since no breeding pairs are formed. The school itself forms the breeding unit. Cods occasionally get landlocked in fresh water, where they become extremely large-headed and cannibalistic.

Similar Species: The Alaska cod, *Gadus macrocephalus,* ranges from the Bering Sea to Oregon and is very similar to the Atlantic species.

The pollack (Boston blackfish), *Pollachius virens,* ranges south to Long Island and reaches 3½ feet and 35 pounds, but it averages only 4 to 5 pounds. It feeds closer to the surface than most members of the family. It is most easily recognized by its lustrous greenish-brown color, white lateral line, and forked tail fin.

The haddock, *Melanogrammus aeglifinus,* has a black lateral line and a dark spot behind the pectoral fin. It ranges south to New Jersey and to Cape Hatteras in deep water and averages 3 to 4 pounds, reaching 25 pounds rarely. Finnan haddie is made from haddock.

The tomcod, *Microgadus tomcod,* is a dwarf species reaching only 15 inches in length. It ranges south to Virginia and may be recognized by the rounded tail fin and comparatively long ventrals, the first ray of which is extended like a filament. It is a shore fish, especially in early winter when it spawns, sometimes ascending rivers for this purpose.

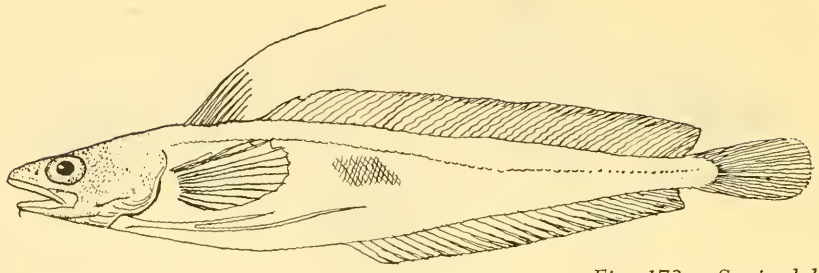


Fig. 173. Squirrel ling.

The California tomcod, *Microgadus proximus,* is found from Monterey to the Aleutian Islands.

SQUIRREL LING: *Phycis chuss*

Size: Up to 2½ feet.
Weight: Up to 8 pounds.
Distribution: From the St. Lawrence to Virginia.
Identification: The shape is elongate, with two dorsal fins, the second much longer than the first. There is a single anal fin. The ventral fins are long and slender and reach the anal fin.
Habits: This fish keeps close to the bottom in waters from moderate depths to 1,800 feet. Its food consists mostly of small crustaceans and fishes. It lays floating eggs, and the young supposedly seek shelter in the mantle cavity of the ocean scallop, *Pectin gigantea.*
Similar Species: There are many species of elongate cods, all of which have the codlike head and single chin barbel, and which have only one or two dorsal fins and are usually nonschooling fishes of deep waters out of the range of the diver. The lings, *Phycis,* form the largest and most common group of these and are, perhaps, most likely to be encountered. Also included are the rocklings, burbots and cusks. (We must refer the reader to the Bibliography for identification of these.) They range from the arctic south to the Gulf of Mexico. The elongate forms of the Pacific are of deep-sea waters.

Flatfishes: *Suborder Heterosomata* (*"differing body"*)

The suborder name is a masterpiece of understatement, for these fishes differ completely in body symmetry from all other fishes. Their head is twisted so that both eyes are on one side. If the eyes are on the right side, the fish is said to be "dextral." If the eyes are on the left side, the fish is said to be "sinestral." Occasionally, a single species shows both dextral and sinestral individuals (the starry flounder, for instance). Some efforts have been made to correlate temperature with the presence of eyes on one side or the other. The eyed side of flatfishes is the up side, both when the fish swims and when it rests on the bottom. This side is pigmented, while the down side, or blind side, is white. Flatfishes are among the most adept of all fishes at changing their colors to match their environments. The color and texture of the substrate are matched very closely as they lie motionless on the bottom waiting to ambush their prey. (The

color photograph shows this adaptive coloration to a remarkable degree in one of the small tropical species.) It is even possible for these fishes to assume checkerboard or polka dot patterns when placed on such a background.

Flatfishes do not rest flat against the bottom as might be supposed, even though they sometimes partly bury themselves. They support themselves slightly off the bottom on their decurved dorsal and anal fins. This is done to allow water to pass more easily out of the gill opening on the blind side and also to allow quick getaway after prey (Orcutt, 1950). These fins may also be used for crawling either forward or backward slowly on the bottom by use of wavelike manipulations of the fin rays. In swimming in open water, the pectoral and tail fins are used. Flatfishes prefer soft bottoms such as sand or mud or fine gravels.

These are all highly carnivorous fishes. Some of them have heavy pharyngeal teeth with which they can crush hard-shelled molluscs and crustaceans.

It is not clear what the relationships of flatfishes are. They have no fin spines and might have been derived from primitive berycoid stock. They are found in all seas, but they predominate in temperate zones. There are many species that are difficult to tell apart.

FLOUNDERS: Family Pleuronectidae

The eyes are large and well separated and the mouth is large and toothed in these fishes. The family may be divided into three distinct parts—the halibuts, the flounders, and the turbots. In the first two, the ventral fins are symmetrical, while the turbots have dissimilar ventral fins. The halibuts have large symmetrical mouths and are the largest members of the family as well as the most primitive. They may be either sinestral or dextral. The flounders have asymmetrical mouths and are mostly dextral fishes. The turbots, as well as having asymmetrical ventral fins and mouths, are usually sinestral, very round in outline, and small in size.

The common names of these fishes are much confused. On our Atlantic Coast, "sole" refers to a member of the flounder group. The following are examples from each of the major groups—halibuts, flounders, and turbots.

HALIBUTS

PACIFIC HALIBUT: *Hippoglossus stenolepis*

Size: Reaches 8 feet.

Weight: Reaches 700 pounds. Rare over 400 pounds.

Distribution: Bering Sea and Alaska south to California.

Identification: Dextral. This fish is usually a plain brownish to grayish color. Halibuts are not as deep-bodied as most flatfish.

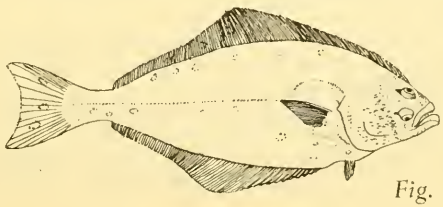


Fig. 174. Atlantic halibut.

Habits: This is a giant fish which, probably because of its size, pursues its food through open water more than do other flatfishes. Halibut are found in shallow to deep water over mud or sand bottoms and are the object of an intensive fishery.

Similar Species: The Atlantic halibut, *Hippoglossus hippoglossus,* ranges from the Arctic Ocean to New Jersey. In the southern part of its range, it keeps to deep water.

NORTHERN FLUKE (SUMMER FLOUNDER): *Paralichthys dentatus*

Size: Up to 4 feet.

Weight: Averages 3 pounds. Common to 10 pounds. Up to 25 pounds.

Distribution: Cape Cod to Cape Hatteras.

Identification: Sinestral. Brownish and mottled with black and white spots.

Habits: The food consists of a wide variety of large invertebrates and fishes. This fish comes inshore in the summer months. It prefers sandy bottoms near beds of vegetation or sandy spots among vegetation and is most often seen partly buried with only the head showing. The beady eyes protruding from the head give this fish away to the diver.

Similar Species: There are several allied species found south to the Gulf of Mexico. The California halibut, *Paralichthys californicus,* is a greenish brown, sometimes mottled species found from San Francisco to the Gulf of California. It reaches a weight of 60 pounds.

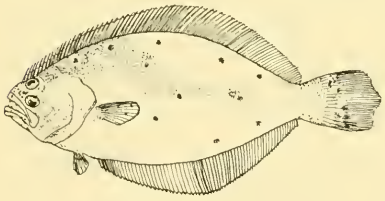


Fig. 175. Northern fluke.

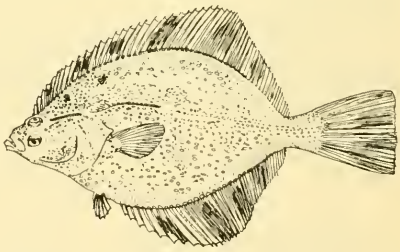


Fig. 176. Starry flounder.

FLOUNDERS

STARRY FLOUNDER: *Platichthys stellatus*

Weight: Averages 2 to 5 pounds. Reaches 20 pounds.

Distribution: Coastal waters from Japan to Alaska and south to Santa Barbara County, California.

Identification: Sinestral or dextral. The body color varies. The dorsal and anal fins are orange-tinted, marked with several conspicuous dark bars.

Habits: Orcutt (1950) studied this fish in detail. The starry flounder rests on various bottoms, but it avoids rock and is most common over soft sand. It buries itself in the bottom by fluttering the dorsal and caudal fins, thus disturbing the sand, which then falls back on its body. If disturbed, it will not move, for it

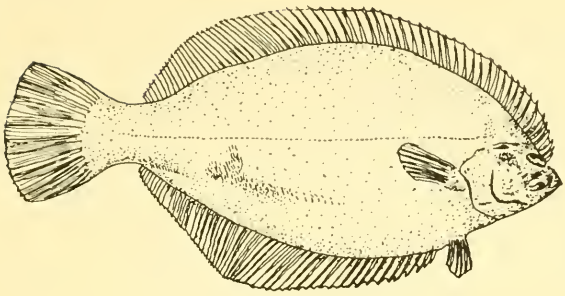


Fig. 177. Winter flounder.

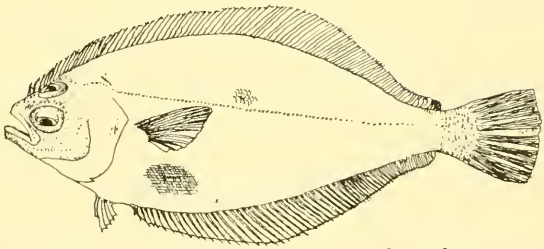


Fig. 178. Sand dab.

depends upon its protective concealment for defense. If the disturbance continues, it will bury itself more deeply or, finally, swim rapidly away.

When starry flounders are first born, their food consists of plankton. At a medium size, they ambush prey from the bottom, but as larger size and maturity are reached and their heavy pharyngeal teeth have developed, they spend more time hunting openly for crustacean or mollusc food. This is a good example of the change in habits that almost invariably accompanies growth (Chapter 2).

The spawning season is winter. As many as eleven million eggs may be laid by a large female. This fish is found from depths of zero to 150 fathoms and can stand a wide variety of salinities. It is one of the most widely distributed of shore fishes. Throughout its range it shows a tendency to be sinestral in some waters, such as those of California, and dextral in others, such as those of Japan. The sinestral form is less common than the dextral.

WINTER FLOUNDER: *Pseudopleuronectes americanus*

Size: Averages about 1 foot. Up to 1½ feet.

Weight: Up to 5 pounds.

Distribution: Labrador south to Georgia. Also found in deeper water to the south.

Identification: Dextral. Mottled like the northern fluke but has no white spots.

Habits: This is the "sole" of the Atlantic. It is inshore in the cooler months primarily and has habits that are like those of the northern fluke.

TURBOTS

SAND DAB: *Citharichthys sordidus*

Size: Up to 1 foot.

Distribution: British Columbia to Baja California.

Identification: The color is brown. The male has orange blotches and dusky-margined fins, and the female is of a lighter color without dusky margins to the fins.

Habits: This delicious little food fish is found the year round on sandy shores.

Similar Species: There are a number of species of this genus on the Atlantic Coast, where they are called "whiffs." They are not usually over 6 inches long.

PEACOCK FLOUNDER: *Platophrys lunatus*

Size: Up to 18 inches. Mostly seen much smaller.

Weight: Up to 2 pounds.

Distribution: Florida and the West Indies.

Identification: There are a number of attractive, small blue spots and larger dark rings arranged in various patterns. The pectoral is very long and filamentous, and the shape is like the eyed platefish.

Habits: The spotted pattern of this fish gives excellent concealing coloration in such places as limestone reefs. It is also found over sand.

Similar Species: There are several turbots ranging in warm temperate and tropical waters of both coasts which resemble this species. The authors have seen the eyed platefish, *Platophrys ocellatus* (*color photograph*), lying in the rocks of gorgonian beds. This fish is very well camouflaged, being distinguishable only when it moves. It reaches 8 inches and ranges from New York to Brazil, but it is common only in the tropics.

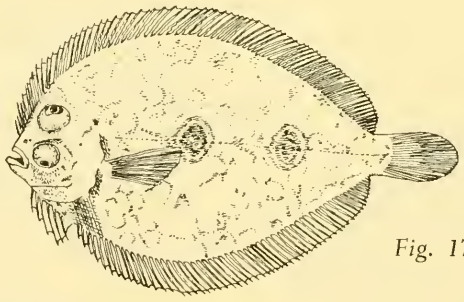


Fig. 179. Eyed platefish.

SOLES: Family Soleidae

These are the most specialized of flatfishes, represented on our shores by a few small species. The true English sole of Europe belongs to this family. Many of the soles are of tropical distribution. None is arctic or north temperate. The mouth is small and very asymmetrical. The eyes are very small and set close together, and the body is very round (except for tonguefishes). They are usually dextral. Soles are uncommon on the West Coast.

HOG CHOKER SOLE: *Achirus fasciatus*

Size: Up to 6 inches.

Distribution: Cape Ann to the Gulf of Mexico.

Identification: There is a pattern on both sides of the body. The blind side is spotted with black, and the eyed side is crossed by dark lines. The pectoral fins are tiny.

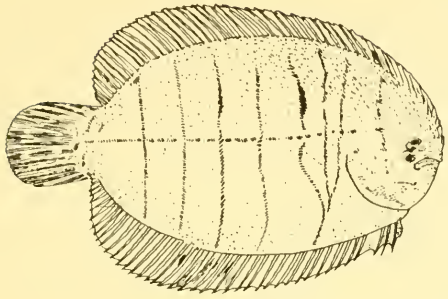


Fig. 180. Hog-choker sole.

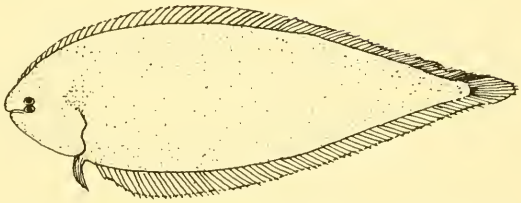


Fig. 181. Tonguefish.

Habits: This is a fish of soft sand or mud bottoms. It will enter brackish or even fresh waters and is omnivorous on invertebrates and sea plants.

Similar Species: The broad sole, *Achirus barnharti,* is a rare fish of Californian waters. It much resembles the hog choker.

TONGUEFISH: *Symphurus plagiusa*

Size: About 6 inches.

Distribution: Cape Hatteras to the West Indies.

Identification: Sinestral. The eyes are very tiny, and the shape is distinctive since there is no definitive caudal fin.

Habits: This is a fish of sandy shores. It is common in some places and probably is somewhat omnivorous in food habits.

Similar Species: The West Coast representative is *Symphurus atricaudus.* It is found from central California to Baja California and is common around San Diego.

Angler Fishes: *Suborder Pediculati*

Completing the list of fishes is perhaps the most extraordinary group of all. The sea "toads," or "fishing frogs" as they are sometimes called, are specialized for a highly carnivorous existence, but many of them catch their prey in a unique way. Although several groups of animals employ lures with which they attract their prey, notably the stargazer and the alligator snapping turtle, no other animals have this lure attached to a "fish pole." This pole is formed of the first dorsal spine, which is inserted on the snout and which overhangs the mouth. These fishes wiggle the lure so as to attract curious small fishes, which are snapped up when they approach closely.

Not all anglers have such a fish pole, but the dominant ones do, so it is fairly typical of the family as a whole. With this sedentary mode of fishing, there are

other changes. The powers of locomotion by swimming are weak. But the powers of crawling along the substrate have become well developed. The ventral and pectoral fins are inserted on angulated, armlike extensions, which makes them very useful as limbs. The small gill openings are behind the pectoral fin. A third adaptation is the highly developed concealing coloration and form. Almost always these fishes are colored to blend with their environment and are very hard to spot. They are also frequently adorned with frills, tabs, and extensions to help destroy their appearance as fishes.

It might be suspected that such great specialization in form and habits would restrict the adaptability of anglers to a few habitats, but such is not the case. The sea has room for sedentary angling forms in many places; anglers are found all over the world, from shallow shores to the deep sea, and over many types of bottoms, from cold temperatures to tropical waters. They are rare, however, on the West Coast. Many of the deep-sea forms, incidentally, have a luminous lure on the end of their fish pole.

Not all anglers angle (in fact, some people say that none do, but it would be hard to explain the fish pole otherwise). Some stealthily stalk their prey, and even though they may sometimes angle, they do not use this means of capturing prey exclusively. All anglers, however, must be close to their food before they are able to suck the food into the huge mouth by a sudden, sucking gulp.

ANGLERS: Family Lophiidae

These are the typical large, depressed angler fishes. They are widespread in the Atlantic and Pacific Oceans, particularly in the temperate zones.

ANGLER (FISHING FROG, MONKFISH, ALLMOUTH): *Lophias piscatorius*

Size: Commonly up to 4 feet.

Weight: Commonly up to 45 pounds. Recorded to 70 pounds.

Distribution: Gulf of the St. Lawrence to Cape Hatteras. Also ranges to the southern tip of South America, but is found only in very deep water in the tropics.

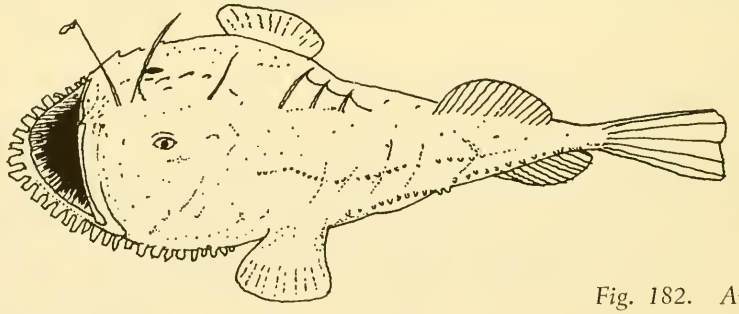


Fig. 182. Angler.

Identification: The shape is distinctive. The bumpy body is beautifully camouflaged to look like a weed or a barnacle-encrusted rock.

Habits: This is an extremely voracious fish that appears to be all head. The mouth is huge and beset with large, recurved teeth. This fish angles for fishes,

but it also eats molluscs and crustaceans. It has even been known to feed on diving birds or to take ducks and loons from the surface by swimming up under them and grasping them from below.

The spawning season is in the late spring and summer. Huge masses of purplish eggs float at the surface. Breder (1948) reports that these masses sometimes weigh as much as 30 pounds or more and measure as much as 1 to 2 feet in width by 40 feet in length.

Similar Species: The West Coast angler, *Lophiomus,* is smaller than the East Coast form. It ranges south to the equator and is very rare in the eastern Pacific. Its normal haunts are the coasts of eastern Asia.

FROGFISHES: Family Antennariidae

These are mostly small tropical fishes, rarely reaching a maximum length of over a foot. They are somewhat compressed and probably none of them angle in order to capture food. Instead they use their very well-developed ventral and pectoral fins as limbs and stalk their prey as a cat stalks a mouse. The very highly developed protective coloration and form-breaking indentations on the body protect them from being noticed by either prey or their enemies. The teeth and mouth are not as large as they are in the previous family, but these are still very voracious fishes which will eat nearly anything they can swallow. Mostly, they are shore fishes, but some live in the floating seaweed, sargasso. They are common in the East and West Indies.

SARGASSUM FISH: *Histrio histrio—Color Plate* 3

Size: Up to 6 inches.

Distribution: Florida to the West Indies.

Identification: Distinguished from other similar species by having the first dorsal ray, which is situated on the snout, bifurcate at its tip. The color matches that of sargassum, or sargasso weed.

Habits: One of the authors has fed and observed this fish in captivity. It may be presented a small guppy or other live food in the fingers. After stalking to within a third of its body length from the food, the sargassum fish opens its mouth suddenly and the food quickly disappears, drawn into the mouth by a current of water created by the sudden expansion of the throat cavity. This fish makes a very interesting pet, but requires large amounts of live food to keep it alive. Only one should be kept in an aquarium for they are quarrelsome. Gill (1908) reports that a sargassum fish 6 inches long swallowed a 4-inch sargassum fish while in captivity. In the wild, it rarely swims but uses its ventrals and pectorals to clamber about in masses of sargasso weed. It is almost exclusively confined to floating sargasso weed, especially in the Sargasso Sea. It may drift far north with masses of this weed in the Gulf Stream. It requires very careful examination of the weed to find this well-camouflaged fish, although it is very common there. The eggs are laid in a floating "raft" about 4 inches long. The eggs of the flying fishes found in sargasso weed were for a long time thought to be those of this fish.

Similar Species: A rare member of this family reaching at least 13½ inches in length is found in warm waters of the West Coast. It is the frogfish, *Antennarius avalonis.*

BATFISHES: Family Ogcocephalidae

The pectoral "arms" of these unique fishes are especially well developed. Their distribution is world-wide on sandy bottoms of warm seas, and they are often seen in harbors.

BATFISH (TOAD, DIABLO): *Ogcocephalus vespertilio*

Size: Up to 9 inches.

Distribution: West Indies to Florida, rarely north to New York.

Identification: Same as for the family.

Habits: The warty, sand-colored body makes this fish very hard to see. It is flattened and broad so as not to cast a shadow (Chapter 2). The authors observed this fish in the harbor of Nassau. It crept slowly over the sandy bottom, searching for its food, which might comprise almost any living object of a size which would fit into the rather small mouth. When approached, it froze; then on close approach, it spread its pectoral and tail fins, exposing a striking banded pattern. This is a display designed to focus an enemy's attention on an apparently dangerous part of the body, in other words, an intimidation based on advertisement (Chapter 2).

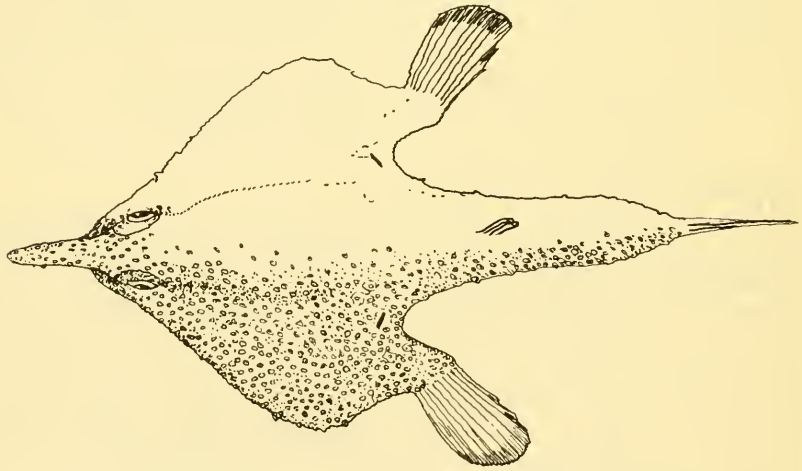


Fig. 183. Batfish.

CHAPTER 10

THE RE-ENTRANTS

Life spread from the place of its origin in the sea up the rivers and to the marshes and lakes of fresh water. From fresh water, the land became populated, and reptiles, birds, and mammals came into being. Since each group of animals tends to evolve by adaptive radiation into all the niches available to it, within the limits of its own body plan, these higher vertebrate groups have returned to the sea, each retaining the basic characteristics of its group, however. The sea turtles and the birds lay eggs on land, and the mammals suckle their young. All breathe air. But each has also become molded to its watery environment, having paddles, flippers, or fins for propulsion, and pursuing fish or other harvest of the sea for food.

The animals included here are those that live and feed in the sea, not those that spend only a small part of their lives there.

REPTILES: Class Reptilia

The age of reptiles is over. For 150 million years the earth—air, land, and sea—was ruled by this scaly clan. Now a remnant, a fascinating remnant to be sure, remains. These are the snakes, lizards, crocodiles, New Zealand sphenodons, and turtles. Of these, two groups in North America have marine representatives, turtles and snakes. (The American crocodile is not a truly marine representative since it lives in brackish waters.)

Turtles: *Order Testudinata or Chelonia*

About 225 million years ago turtlelike reptiles first appeared, having evolved from a primitive reptile stock. Even at that time turtles were marked by the beginnings of a shell, consisting of an upper part, the carapace, and a lower one, the plastron. They lost teeth and replaced these with a horny beak. By the Cretaceous Period, over 100 million years ago, modern turtles were present. Shelled and toothless, the turtles have conservatively remained to this day, spreading over the earth to the ponds and rivers, the deserts, and to the sea. But while their habits vary greatly, their body form has been remarkably unchanged. Clumsy as this body may appear, it is persevering. No other air-breath-

ing vertebrate group has lasted more or less unchanged as long as turtles have. The life span of turtles is not precisely known, but they are probably the most long-lived of all animals, surpassing ages of 100 to 150 years.

SEA TURTLES: Family Cheloniidae

Sea turtles probably arose from marsh-dwelling, primitive shelled turtles as long ago as the Triassic Period (over 150 million years ago). They live in the sea but betray their role as converted land animals by breeding on land and by breathing air. Their feet have turned to flippers, and the manner of propulsion is different from fresh-water aquatic turtles since the flippers are not used as paddles but as "wings." They literally fly through the water. This is an efficient mode of progression since these turtles are able to cover 100 yards in 10 seconds and thus qualify as the speediest of reptiles, with the possible exception of some desert lizards. (The leatherback turtle, of a different family, is probably even faster than these.) On the fore-flippers of the male is a single claw used to grasp the female during copulation. This claw can inflict a painful wound on the unwary. Males also have a long tail.

For all turtles, enclosure within a shell poses a respiratory problem. Since the lung cannot expand within a rigid box, the exposed areas of skin around each of the four legs act as little diaphragms, expanding for inhalation. But in the case of sea turtles, the shell has been somewhat reduced, and the plastron has a longitudinal hinge which does, in fact, allow the chest to expand so that great quantities of air can be inhaled for prolonged submersion. The authors have held young hawksbill turtles in their hands and have found this accordionlike expansion to be marked on inhalation.

Sea turtles come onto land to lay eggs and thus expose themselves to the hardships there, particularly the danger of that rapacious carnivore, man. In the late spring and summer primarily (some sea turtles breed the year around), the females, heavy with eggs, drag themselves onto a sandy shore. There, above the high-water mark, a neat little hole is delicately dug with the hind flippers and up to three hundred eggs are laid, a record for turtles. Then the hole is filled in, and the fore-flippers aid in generally disturbing a large area of sand so that the exact location of the nest is obscured. During the whole time, the mother's eyes secrete tears profusely as if the whole project were breaking her heart, but this wetness is probably only to protect the eyes, which are accustomed to salty, aqueous surroundings. Then she drags herself, exhausted, back to the sea. The young, only an inch or so in carapace length, hatch at summer's end and head away for a precarious life at sea, where mortality is high. They are eaten by crabs, sea birds, and fishes. At these egg-laying periods, the females are often caught, and eggs are confiscated by man. Large numbers of turtles are also netted or speared at sea. The result has been the decimation of a valuable food source. It will probably take international treaty to save at least one species, the green turtle, from eventual extermination, for modern freezing methods have increased the demand for them. Turtle populations in their present state could not stand concentrated fishing. However, restored to former abundance and with proper conservation, the sea turtles could once again become an important and valuable food source.

There are only four genera of sea turtles, all of world-wide distribution in

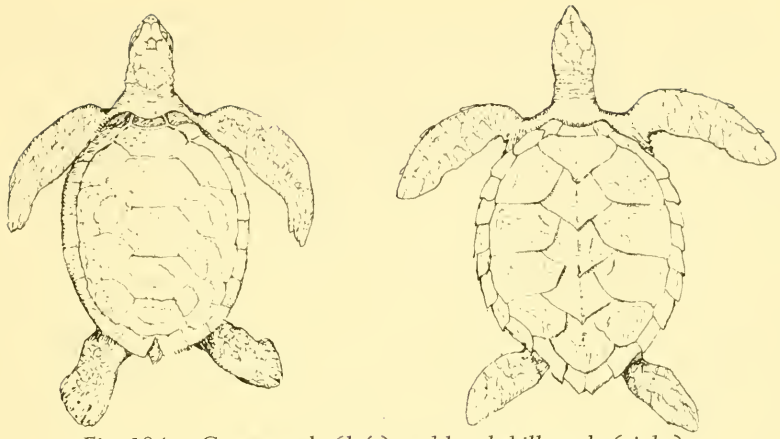


Fig. 184. Green turtle (left) and hawksbill turtle (right).

warm seas. The habits of none of these are well known, and those of one, the ridley, is shrouded in mystery.

GREEN TURTLE: *Chelonia mydas*

Size: Up to 4 feet.

Weight: Up to 500 pounds. Formerly reported to 800 pounds or more.

Distribution: Gulf of Mexico to Caribbean and Atlantic. Straggles north to Cape Cod. On West Coast north to southern California. Cosmopolitan in warm seas.

Identification: The carapace is smooth and brownish in the Atlantic, greenish to olive-brown in the Pacific. The head is small and blunt and, unlike other sea turtles, bears only one pair of prefrontal shields on the top of the snout between the eyes and nostrils (other sea turtles have two pairs).

Habits: The habitat of this turtle is restricted to shallow shoal waters (2 to 4 fathoms) where there is a good growth of eelgrass, *Zostera,* or other marine vegetation, which it eats almost exclusively, although it will eat some invertebrates. Near these vegetable gardens, the green turtle requires rocks or reefs, in the protection of which it sleeps. During sleep, the metabolism is low so that little oxygen is required. It is occasionally seen out at sea. It has a mild temperament.

Formerly, the green turtle bred over a wide area, but its numbers have been greatly depleted, and the Atlantic form is now found chiefly in Central America and off Ascension Island. It was exterminated from Florida shortly after the turn of the century. This is the most valuable of all reptiles and could be, if properly restored, a major food source. Its flesh is exquisite and the eggs are a delicacy. This animal is not now on the verge of extinction but it could shortly be brought to such a state with an increase in fishing pressures.

HAWKSBILL TURTLE: *Eretmochelys imbricata*

Weight: Common at 40 to 50 pounds. Large at 100 pounds. Up to 280 pounds.

Distribution: Gulf of Mexico and Caribbean. Tropical Indo-Pacific north to Baja California.

Identification: The shell, familiarly known as "tortoise shell," is heart-shaped and is a beautiful mottled brown, reddish, and yellow, as are the head and flippers. Old animals have the shell pattern obscured by encrusting algae and silt. The shields of the carapace are imbricated like shingles on a roof and can inflict cuts. The head is small with a hawklike beak.

Habits: The range of habitat is more extensive than is the case for the green turtle. Muddy or sandy bottoms or reefs are inhabited. Still, it stays in shallow coastal waters. In food habits, it is omnivorous, but no careful scientific study of this turtle has been made. It is known to eat the Portuguese man-of-war, keeping its eyes closed to avoid the tentacles. It lays up to three hundred eggs in summer. The authors found it fairly easy to approach. If the swimmer hovers above one in the water, waiting until the turtle is about out of breath, he can dive straight down on it and catch it with his hands. Care should be taken to avoid the beak since hawksbills will occasionally bite. Large ones can give a swimmer quite a ride. The shell and eggs of this turtle make it commercially valuable, and though it is not depleted to the extent of the green turtle, care should also be taken to avoid decimation.

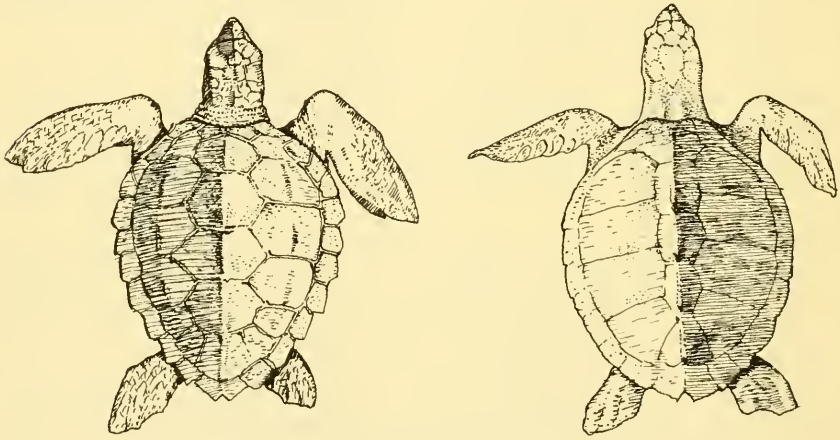


Fig. 185. Loggerhead turtle (left) and ridley turtle (right).

LOGGERHEAD TURTLE: *Caretta caretta*

Weight: Rare over 300 pounds today. Reliably recorded to 900 pounds; doubtfully reported to 1,600 pounds.

Distribution: The tropics north to Nova Scotia and southern California. Most common in warm waters but is found out of tropics more than other sea turtles. World-wide in warm seas.

Identification: The shields on the back are not imbricated. The plastron is heart-shaped, broadest under the fore-flippers, and brown to reddish in color. The head is large. The shape of the carapace separates it from the ridley.

Habits: This turtle is a confirmed wanderer over the whole area of the continental shelf and rarely to the open sea. It is often seen basking on the surface over waters of moderate depth. It nests, or used to, north to Virginia. This is not a commercially valuable species. It is pugnacious and will bite savagely at

times. It feeds mostly on bottom invertebrates like crustaceans and molluscs and also eats jellyfish and fish.

RIDLEY'S (KEMP'S LOGGERHEAD): *Lepidochelys olivacea*

Size: Recorded to 28 inches in carapace length. The smallest of the sea turtles.

Distribution: Shores of the Gulf of Mexico, eastern coast of Florida and north to Massachusetts and England in the Gulf Stream (as young). Not in Caribbean. Baja California to Chile.

Identification: The carapace is nearly round, broadest at its middle, and is gray in the Atlantic and olivaceous in the Pacific. The head is large.

Habits: This is one of the true mystery animals of the sea as Carr (1955) so excellently points out. Though it is not rare in its range, very little is known of it. It prefers shallow, protected waters (near mangroves on the East Coast) and is most abundant in the Florida Gulf coast waters. Its food seems to consist of crustaceans, molluscs, and sea plants. Its temper is exceptionally short, and handling one can be risky business.

The West Coast ridley turtles are known to breed on beaches in summer in the normal sea turtle fashion, but the Atlantic species is not known to breed at all! This is Carr's "riddle of the ridley," and it can easily tax the imagination of the best of us. It seems more than logical that turtles should breed, but no one has ever seen the eggs, nests, copulation, or a pregnant female of the Atlantic ridley. No one has ever seen a young one of under a few months old. Some people think that the ridley is a sterile cross between a green turtle and a loggerhead and, like the mule, is at the end of the road, but this, as well as numerous other suggestions, appears to be ill-founded. Probably on some obscure beach somewhere this turtle breeds. Where? When? No one knows, but the probability is that this occurs in the Gulf of Mexico. The breeding of the ridley is not the only strange thing about this animal. Its very name is a mystery. The origin of the odd name "ridley" is not known. And why isn't it found in the Caribbean where suitable habitat is apparently plentiful? Again, no answer.

LEATHERBACK SEA TURTLES: Family Dermochelidae

One must resort to superlatives to describe the leatherbacks. They are the most aquatic, most powerful, the fastest, largest, and among the rarest and most peculiar of all the turtles. They are placed in an entirely different suborder from all other turtles, Athecae ("no shell"), because they have greatly reduced both plastron and carapace and have a leathery skin over their massive bodies. The black skin of the carapace has seven longitudinal ridges. The unclawed flippers are huge, and it is said that these turtles can travel at remarkable speeds, but they have never been clocked. There is one species.

LEATHERBACK SEA TURTLE (TRUNK TURTLE): *Dermochelys coriacea*

Weight: Recorded to 1,200 pounds. Probably reaches 1 ton.

Distribution: Tropical seas. Recorded north to Nova Scotia and Vancouver.

Identification: Same as for the family.

Habits: Very little is known of this pelagic turtle. It comes into shallow water seldom, preferring the open sea. In the summer it breeds on sandy beaches as

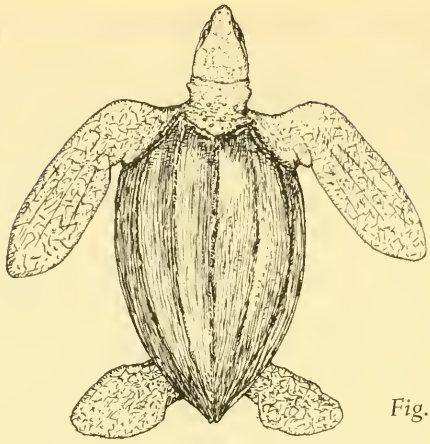


Fig. 186. Leatherback turtle.

other sea turtles, and the lucky swimmer or beachcomber may see one then. If so, he should not molest it but observe all he can and contact the nearest scientific institution as soon as possible. This is a rare animal of great scientific interest.

Leatherbacks are powerful and able to inflict damage with their beak and flippers. They frequently roar or scream when molested. They probably are more or less omnivorous.

Snakes: *Order Squamata*

There is one small family of sea snakes typical of the Indo-Pacific and represented in our seas by one species.

SEA SNAKES: Family Hydrophidae

These snakes live exclusively on the sea, never coming on land, except for one Indo-Pacific species which comes ashore to lay eggs. They are, if placed on land, almost helpless since they have lost the large, flat belly scales of most snakes and cannot crawl on land except by considerable effort. But in the sea, they are completely at home and are excellent swimmers. Their tails are compressed like oars and even their bodies are a little compressed. Their nostrils are placed on the top of the snout for easy access to surface air. Under water, the nostrils are closed by a valve. Sea snakes are closely related to the coral snake-cobra clan, all members of which possess a powerful neurotoxic poison. The sea snakes may surpass even these in the drop-for-drop power of their venom, but, fortunately, they are very reluctant to bite. Fishermen remove them from nets with their bare hands, and these snakes are not known to attack or bite humans in the water. They are almost exclusively fish-eaters. They bask on the surface almost motionless. Small fishes gather around them, as they would gather around a floating stick, and are captured and eaten. Sea snakes inhabit shallow coastal waters, particularly near river mouths, and shun the deep sea. They are ovoviviparous or oviparous. At times they congregate in huge masses at the surface. One such mass was reported to be 10 feet wide and 60 miles long. The reason for such congregation is not known, but it may be for copulation. When so congregated, they lose their normal alertness and are easily approached.

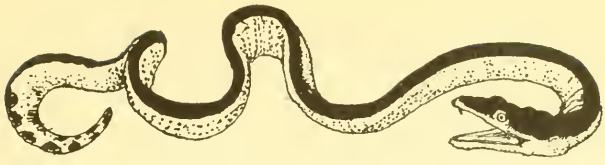


Fig. 187. Yellow-bellied sea snake.

YELLOW-BELLIED SEA SNAKE: *Pelamis platurus*

Size: Up to 3 feet.

Distribution: Ecuador to the Gulf of California. West to Africa.

Identification: The dorsal half of the body is dark bluish brown, and the ventral half bright yellow to orange. The tail is yellow with dark bars.

Habits: Same as for the family.

BIRDS: Class Aves

There are several families of birds that feed by diving in the sea, particularly near land, and a great number that float or fly over the sea. None of these is exclusively a marine group since they go beneath the surface only to feed. The swimmer may be treated to seeing birds swimming beneath the surface, where he will be startled by the speed these animals can attain. Underwater photography of diving birds is a fascinating pastime. (We refer the reader to the excellent field guides to birds, given in the Bibliography, that are available for identification.) A list of prominent families that dive to feed in the North American seas and swim below the surface follows:

Loons (Gaviidae)
Grebes (Colymbidae)
Cormorants (Phalacrocoridae)
Some ducks and mergansers (Anseridae)
Auks, murres, and puffins (Alcidae)

Many other birds dive just below the surface but do not swim under water. Some of these are shearwaters, petrels, tropic birds, pelicans, gannets, man-of-war birds, some ducks, gulls, and terns.

MAMMALS: Class Mammalia

Four groups of mammals enter the sea: sea otters, seals and walruses, manatees, and whales and dolphins. The last two groups are exclusively marine, never appearing on land. The others enter the sea mainly to feed, although the sea otter has been driven to become more and more exclusively marine in its habits because of persecution by man.

Carnivores: *Order Carnivora*

There is some confusion surrounding the term "carnivore." Used as a reference to habits it means "of flesh-eating habits" and may apply to sharks, killer

whales, cats, etc. Used as a term of scientific classification, it applies to a specific order of mammals, which includes bears, raccoons, cacomistles, mongooses, weasels, otters, skunks, dogs, cats, seals, and walruses. It is thus possible to speak of a carnivorous, or meat-eating, carnivore (cat), an omnivorous, or both animal- and plant-eating, carnivore (bear), a piscivorous, or fish-eating, carnivore (seal), and even an herbivorous, or plant-eating, carnivore (panda).

WEASELS: Family Mustelidae

The sea otter is the only seagoing member of the weasel family and is on a par with the wolverine as being the largest member of that family. Many of the weasels have aquatic tendencies, but the sea otter is better adapted for living in water than any other weasel.

SEA OTTER (SEA BEAVER, KALAN, A-MI-KUK): *Enhydra lutris*

Size: 3½ to 4½ feet.

Weight: 25 to 75 pounds.

Distribution: Baja California coastwise to Alaska, the Aleutians, and Japan.

Identification: The foot-long tail (short compared to other otters), short legs, and otterlike face make this animal unmistakable. The color is dark brown to nearly black, lighter about the head and neck.

Habits: It is almost impossible to be unemotional about this animal, for it is an immensely appealing, yet tragic one which has suffered greatly at the hands of man, its only enemy besides the killer whale and sea lion. Its story is briefly told here and serves as an example of the worst kind of man's abuse of a valuable resource as well as being an example of his sometimes consuming greed and stupidity.

The sea otter was discovered in 1737. Evidence points to the fact that it was a different animal then than it is now. Early reports indicate that the sea otter much resembled the seal in habits, going to the sea to feed and lying in droves on the land to rest and bear young. Now, through great diminution in numbers and constant persecution, it is principally a beast of the kelp beds near shore, rarely coming onto land. It is probably a much more wary animal than it was, and it is difficult to see and to approach except when it is sleeping on the surface.

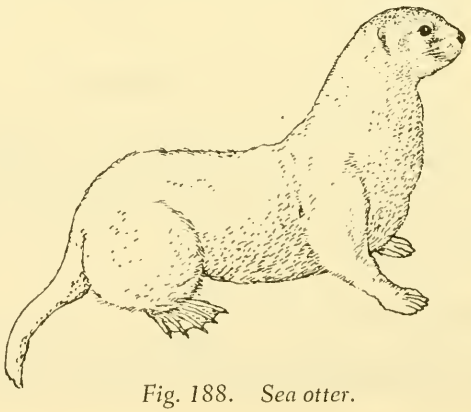


Fig. 188. Sea otter.

The persecution that caused this change involves the fur, by far the most valuable fur, pelt for pelt, that is known. Fur dealers use the sea otter's fur as the standard of excellence against which all other furs are rated.

Very shortly after the sea otter's discovery, the massacre began, first by Russians in the north and later by West Coast Indians and the Spaniards of California. Killing them was a simple matter. About all one had to do was walk up to them and club them to death. Upon the first blow of the club the otter would in amazingly humanlike fashion lie down, cover its eyes with its forepaws, and submit itself to the punishment. In the water, mothers with cubs were very easily taken since they would under no circumstances leave their young. It took only about eight years to exterminate the St. Paul herd of the Pribilof Islands, and by as early as the mid-1800's the sea otter existed only as a pitiful remnant over its wide range. The length of time taken for this job of near extinction was only about a third of the time that it took to equally reduce the American bison. The price of a single pelt rose from $6 to $7 in 1785 to $2,500 in the 1920 fur boom.

The mother is very protective toward her pup, cradling it when fleeing an enemy, and, when asleep, she floats on her back, holding the pup in her arms. Sea otters can make sounds variously described as "whimpering" or "crying" in fright and "crooning" to young.

The sea otter feeds in kelp, from the shore to 30 miles out to sea, on crustaceans, molluscs, sea urchins, and some fish. It can dive to 300 feet with the aid of its paddlelike hind feet, but it mostly feeds at depths of 30 to 100 feet. After dives of a quarter of a minute or up to four or five minutes, the otter surfaces, floats on its back, and eats the morsels off the platter of its chest.

They may be seen today in scattered bands throughout much of the former range. Herds are making a comeback in Monterey Bay.

Seals: *Suborder Pinnipedia*

These animals are sometimes separated from the carnivores as a full order, but this is probably not justified since they are clearly derived from carnivores and closely related to them, the chief difference being the flipperlike limbs. There are three families, all of which have fish- or mollusc-eating habits, and most of which are of northern seas. They bear young and sleep on land, sometimes gathering in large groups in definite rookeries to do so. The huge bulls gather the cows into large harems for mating.

All members of this group are intelligent, swift in the water, and of large size. They certainly could be dangerous if molested but are usually trusting in the water and allow close approach. Swimmers have met the California sea lion under water and found it to be curious but a little too large for comfort. In the presence of pups they are probably dangerous. Young seals, however, are docile and friendly. The huge walrus, which the swimmer will probably never meet, is definitely a dangerous fellow.

EARED SEALS: Family Otariidae

These are the familiar seals and sea lions of the fur industry, San Francisco's Seal Rock, circuses, and zoos. All of them are of rich brown color and have

Fig. 189. The California sea lion, Zalophus californianus, *is an inveterate circus performer. Under water, the irascible males or females with pups can be dangerous. Otherwise, this is an intelligent, friendly, and playful animal.*

small external ears. All can stand erect on the large fore-flippers (used for propulsion under water in a winglike manner), and all can rotate the rear limbs forward so as to be able to move fairly rapidly on land. They are found in the North Pacific and in the South Pacific but not in the warm waters in between.

CALIFORNIA SEA LION: *Zalophus californianus*

Size: Bulls up to 8 feet in length. Cows up to 6 feet in length.

Weight: Bulls up to 500 to 620 pounds. Cows up to 300 pounds.

Distribution: Southern Mexico to northern California.

Identification: As in other species of the family, the bull is thick-necked, heavy-shouldered, and much larger than the slim cow. The bull also has a high forehead. The color is a yellow brown (darker when wet) to almost black.

Habits: This is a very playful animal, gregarious and active. In the water, the tendency on the part of the swimmer would be to play with them, but all except the very small ones are liable to get a bit rough. They probably would not attack a swimmer if left unmolested and if not in the presence of the pups (which are cared for and defended by the females, but which may be killed by the bulls). This species does not gather into large harems for breeding. The loud honking bark is familiar and is uttered when feeding, playing, or as a warning. Adults eat about twelve to fifteen pounds of fish and squid a day, although the males in rut take no food at all.

Similar Species: The valuable fur seal, *Callorhinus ursinus*, is about the same

size as the California sea lion. It breeds on the Pribilof Islands and may reach south to California in winter. It has a dense yellow-brown underfur which California sea lions lack. Its only enemy is the voracious killer whale.

The huge Steller's sea lion, *Eumetopias jubata,* reaches a weight of 1,800 pounds or more and a length of over 12 feet (bulls). Its voice is a long roar. The distribution is from the Farallon Islands off San Francisco to the Bering Strait.

SEALS: Family Phocidae

These seals have no external ears and cannot turn their rear flippers forward for locomotion on land. These are the most aquatic of the Carnivora. Progression on land is very clumsy, hardly being more than a squirming or wriggling, in which the body is dragged ineffectually by the small front flippers. In water, however, they are swift and graceful fish-eaters. Propulsion in the water is by means of the rear flippers which are used in undulating fashion like the fin of a whale or fish. These seals do not usually congregate to breed (the elephant seal does). The single pup is born, a little ball of white fur, in some secluded place on shore or on ice in summer. Most are of arctic or cold temperate distribution.

HARBOR SEAL (HAIR SEAL, LEOPARD SEAL, COMMON SEAL): *Phoca vitulina*

Size: Up to 5 feet (for both sexes).

Distribution: South from the arctic to the Carolinas and Baja California.

Identification: Color is yellow-gray, spotted with dark, indistinct blotches. Some are dark brown, spotted with yellow.

Habits: These are the common seals of our temperate coasts. They are friendly and engaging, especially as pups, and, if tamed early enough, could make fine and engaging swimming companions. They can utter a coarse bark. They eat about ten pounds of fish, squid, and crustaceans a day near the bottom. The killer whale, large sharks, polar bears, and man are its chief enemies. They are agile and speedy swimmers.

Similar Species: Few species of seals go south of the St. Lawrence and Alaska. The gray seal, *Halichoerus grypus,* is a large seal, the bulls reaching 6 to 9 feet and 800 pounds and the cows reaching 6 feet and 700 pounds. The gray seal resembles the harbor seal in coloration, and it shares the same common names, but it is heavier and less active. It ranges south to Maine and straggles to New Jersey.

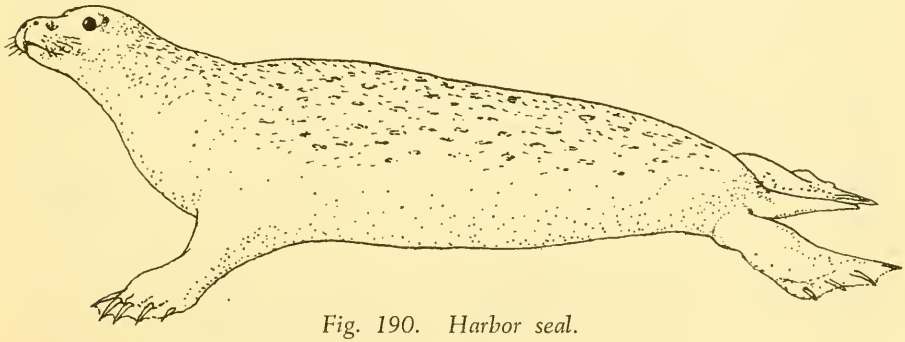


Fig. 190. Harbor seal.

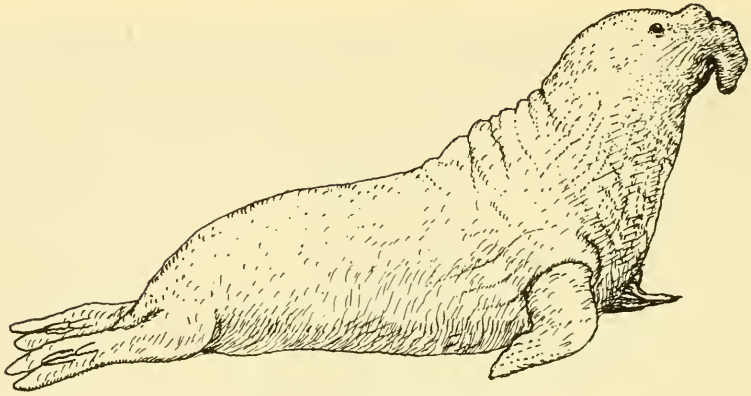


Fig. 191. Elephant seal.

The West Indian seal, *monachus tropicalis,* is nearly extinct and should be looked for. Very little is known of it. It is brown above and pale below, and trusting and sluggish in habits. Formerly it occurred in the West Indies north to Florida. Any seal seen in that area should be reported to the United States National Museum in Washington, D.C., or American Museum of Natural History in New York City.

The elephant seal, *Mirounga angustirostris,* is the largest of living Carnivora in length and weight. Bulls reach 18 feet and 5,000 pounds. The cows are two-thirds as large. The major herd now known is one on Guadalupe Island near San Diego, where it is protected by law. This herd has spread to establish new colonies on several surrounding islands. Formerly it occurred over the entire West Coast from Mexico to British Columbia. The name is derived from the male's inflatable snout and its huge size. Its food probably consists of fish and invertebrates, caught at night. By day they bask on shore and can be approached closely. Its valuable oil was the cause of its near extinction by man.

Sea Cows: *Order Sirenia*

The head and mustache of a walrus, flippers of a seal, lack of hind limbs, and odd, spatulate tail (on the manatee) identify the two living members of this order, the Indo-Pacific dugong and the manatee of the Gulf of Mexico and the West Indies. It is thought that these animals gave rise to the mermaid tales of a few years ago. The scientific name gives credence to the fable by being adapted from "sirens," the voluptuous singing maidens that so tempted Ulysses. Sea cows are reported to be able to whistle, but they do it through their unmaidenly, valvelike noses. If former voyages had not been so protracted in length, it would otherwise be difficult to imagine how a sailor, even a hot-blooded one, could confuse a maiden and a sea cow.

Both species have been much reduced. The dugong is in special danger of extinction.

MANATEES: Family Trichechidae

MANATEE (SEA COW): *Trichechus manatus*

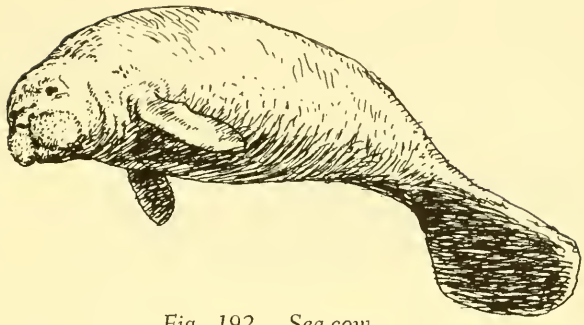


Fig. 192. Sea cow.

Size: Up to 12 feet. Averages 7 to 8 feet, probably when it is subadult.

Weight: Up to 1 ton. A male 7½ feet long weighed 432 pounds.

Distribution: The West Indies, the Atlantic Coast of Central America and Mexico, and the coasts of southern Florida. Summer extensions up the eastern coast of Florida and thinly up the Texas coast. Range does not include northern Gulf of Mexico.

Identification: Same as for the family.

Habits: This is a docile, sluggish vegetarian which browses on aquatic vegetation in shallow bays, lagoons, river mouths, and rivers. The upper lip, with its stiff bristles, gathers the food. Manatees travel singly or in small family groups. They are hard to see because of a predilection for turbid water, but otherwise they should not be too difficult to approach under water. Upboiling on the water's surface in series indicates their direction and progress as they swim in shallow rivers or bays. The ribs of manatees are remarkably heavy and dense and probably aid in keeping the animals submerged. Fossil manatee ribs, black and subcylindrical, are not uncommon objects on some Florida beaches. The manatee has been much persecuted for its oil and flesh and deserves vigorous enforcement of the Florida law which protects it. (There is a $500 fine for killing or molesting a manatee.)

Whales, Dolphins, and Porpoises: *Order Cetacea*

The origin of whales is unknown although they have been in existence for nearly the entire Cenozoic Era (the age of mammals). They form the most fishlike of the re-entrants but are immediately distinguishable from all fishes by the horizontal tail flukes and the movements of the tail, which are up and down rather than lateral. These animals suckle their young in the sea, but they alter the normal mammalian suckling pattern. Instead of the young suckling from the mother, a feat that would be difficult under water, the female pumps milk into the calf by muscular action. This process is very quick. Occasionally, a mother whale and calf will somehow miss connection, and gallons of rich milk flow into the water, turning it white. The nostrils are on the top of the head and form the blowhole which may be opened and closed by a valve. The spout of large whales is the result of the exhalation of air and water vapor from this blowhole. All cetaceans are carnivorous, but the size of prey varies greatly. These

animals possess no sense of smell and probably hunt their fish or plankton prey chiefly by sight or taste. Their intelligence is high as a group, that of the bottle-nosed dolphin being comparable to that of a dog.

Whales have been much reduced by whaling. Supposedly, international law regulates the yearly catch, but this law unfortunately shows few signs of restoring former whaling grounds. Most of the smaller dolphin species are rare and if seen, especially if they are stranded on beaches, should be reported to the nearest scientific institution.

The habits of most of these animals are very poorly known. Good accounts of many of them are found in Norman and Fraser (1938). Their distribution is world-wide in all seas. The larger ones are more typical of cold waters where the plankton is concentrated.

Whalebone or Baleen Whales: *Suborder Mysticeti*

These are the most gigantic of all living things and, indeed, the largest animals that have ever lived. The suborder name refers to the fact that they have no teeth. Instead, baleen or whalebone, a horny epidermal derivative, hangs down in plates from the palate. This is used to strain plankton from sea water. A huge mouthful of water and plankton is taken into the mouth. The tongue presses up against the baleen plates and expels the water through the screen of baleen which holds the plankton. Then the plankton is swallowed. Such huge animals, it might be supposed, could not possibly find enough plankton to eat, but marine crustaceans, especially krill (euphausians) and copepods, become amazingly plentiful in summer in cold seas. So thick does the water become with them that powerful ships are slowed to half their speed when traveling through such water. The baleen whale's spout, which is thrown vertically upward, is double because of the paired blowhole.

BLUE WHALE (SULPHUR-BOTTOM WHALE, RORQUAL): *Balaenoptera musculus*

Size: This is the largest animal that has ever lived. Averages 60 to 80 feet long. Up to 103 feet.

Weight: At 76 feet it weighs 63 tons. At 89 feet it weighs 119 tons.

Distribution: All seas, but particularly arctic and antarctic waters.

Identification: The throat and chest have a series of longitudinal pleats. The body is slender and tapering for a whale, and the top of the head flattened and broad.

Habits: These are perhaps the swiftest of large baleen whales, said to be able to attain 12 miles per hour. The young are 24 feet long when born and take one year in gestation. This embryonic growth rate is astonishingly fast and probably represents a record for any type of growth rate. These are not aggressive animals and are probably quite timid. Their only enemies are parasites, the killer whale, and man. The most destructive of these is man, but the most fearful, to the human eye at least, is the killer whale.

Similar Species: The other common rorqual or ridge-throated whale is the 65-foot finback, *Balaenoptera physalus*, which has small flippers, a ridged back,

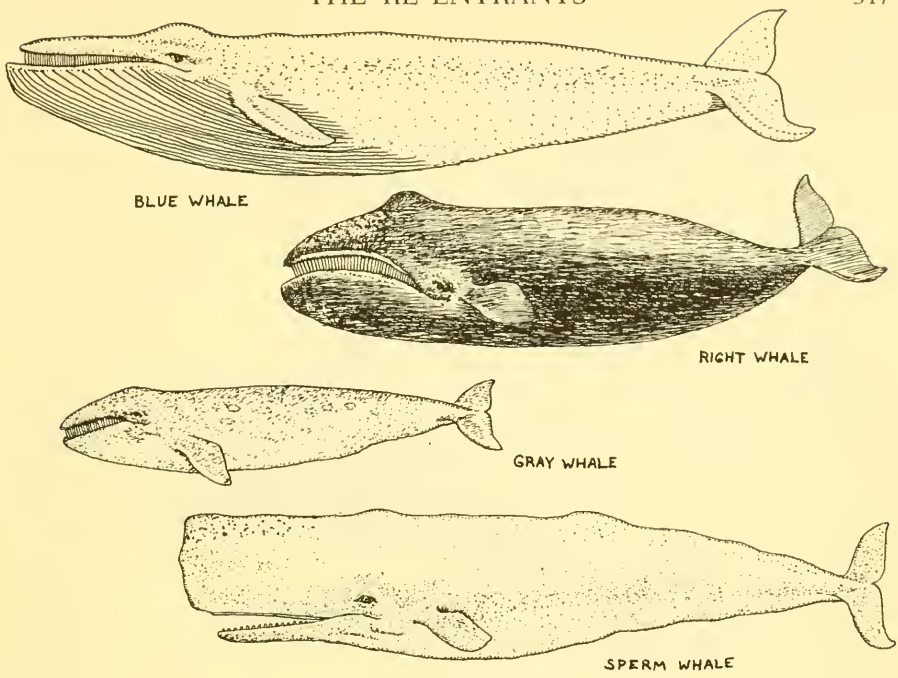


Fig. 193. Whales.

and a wedge-shaped head. The humpback whale, *Megaptera nodosa*, is stocky of body and has very long, knobby flippers. It reaches 50 feet in length. Both of these are found in both the Atlantic and Pacific Oceans.

The right whales (*fig. 193*), *Eubalaena* species, and the bowhead whale, *Balaena mysticetus*, have no dorsal fins or throat ridges, but have huge heads with arched mouths and broad, rounded flippers in contrast to the tapering flippers of rorquals. Both are found in both the Atlantic and Pacific and reach 60 feet or more. These are slower whales than ridge-throated whales and were so persecuted by whalers that they are now rather rare. They are increasing slowly under international protection.

The California gray whale, *Eschrichtius glaucus* (*fig. 193*), is a medium-sized whale reaching 40 feet in length. It is gray in color and has a small head. Formerly it abounded on coasts, especially in lagoons and estuaries from Baja California north to Japan. Now it is rare but is increasing under protection. It is said to be so terrified in the presence of killer whales that it offers no fight, merely lying on its back and hanging out its tongue, which is eaten by the killers.

Toothed Whales: *Suborder Odontoceti*

These whales have teeth and never possess baleen. There is only one nostril so the spout is single. Most of the species of the suborder are small, and a great number of them are rare and very poorly known. Many of them eat squids, but they are mainly fish-eaters.

SPERM WHALES: Family Physeteridae

There are only two species, one of which, the pigmy sperm whale, is small and rare. The name "sperm whale" refers to the large reservoir of oil or spermaceti that is found on the top of the head, giving it a squarish appearance.

SPERM WHALE (CACHELOT): *Physeter catodon*

Size: Males reach up to 85 feet, but usually not over 60 feet. Females reach up to one-half this length.

Distribution: Tropics to subarctic waters of all seas.

Identification: The shape of the huge head with the narrow, toothed lower jaw is distinctive. The spout is low and directed forward.

Habits: This is Melville's "Moby Dick." The sperm whale is able to sound to great depths (to half a mile or more) and can stay under for as long as an hour to hunt for its food, the giant squid. Scars of squid suckers and tentacle hooks are to be found on its body, mostly about the head. The physiological strain of such prolonged deep dives is tremendous and how the whale stands it is not known. Formerly this whale traveled in large schools of a hundred or more, mostly composed of cows and calves, with a few bulls. Now they are much rarer and schools of fifteen to twenty are large. This is a swift whale, able to attain 12 knots. The sperm whale has no enemies except man. Even the killer whale cannot attack it successfully. There is a report of a small group of killers attacking a large sperm whale while the latter was basking on the surface. It soon woke and maimed one of the killers in its jaws and was last seen pursuing the others, which it probably could not catch.

Ambergris, the valuable perfume base, is taken from the intestine of this whale. Sometimes it is found cast up on coasts. One mass weighing 924 pounds was found cast up on an Australian beach and was valued at $120,000. Usually the pieces found in whales weigh only a few ounces. This valuable animal is being hunted at the present day, and it is a question how long it can stand hunting pressure. It seems to be holding its own, but not increasing.

PORPOISES AND DOLPHINS: Family Delphinidae

There are many species of these interesting, very intelligent, small cetaceans. (We must refer the reader to the Bibliography for all but three of them.) Many species are quite rare and are of great zoological interest. Observations of them in the sea would be of value. The term "dolphin" and "porpoise" are commonly used interchangeably. "Dolphin" is also the name of a fish, *Coryphaena.* As used here, however, it only includes the small, beaked members of this family. "Porpoise" refers to the small beakless species. The larger species are known by various other names and include the narwhal, beluga, grampus, blackfish, beaked whales, and killer whales. Most of these are rare or of northern seas, and some are not strictly of this family. All are very swift, agile, and active carnivores, mostly on fish.

BOTTLE-NOSED DOLPHIN: *Tursiops truncatus*

Size: Reaches almost 12 feet, but 9 feet is large.

Distribution: Cosmopolitan in warm seas.

Identification: The color is a slaty, dark, bluish-gray. The beak is short, and there is a high forehead.

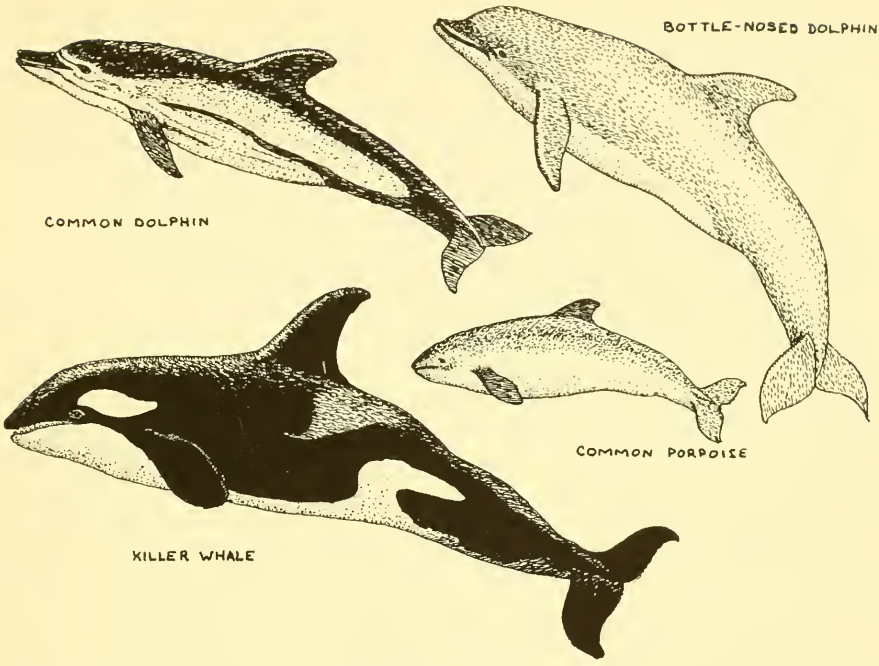


Fig. 194. Porpoises and dolphins.

Habits: This is the best known dolphin, both to swimmers and to inshore seafarers. It is the only dolphin commonly seen in river mouths, bays, and beach areas of the Atlantic Coast. It is less common on the Pacific Coast, perhaps because the waters are colder there.

The favorite food of the dolphin is mullet, which it pursues by sight. It also has been observed to dash into a school of these fishes and send one aloft with a stroke of its tail. The mullet then falls into the dolphin's awaiting jaws.

Dolphins travel with great ease through the water and are among the fastest of swimmers, capable of playing about ships' bows at 40 mph or a little over. They breathe at the surface every ten to sixty seconds and are capable of a six-minute submersion. Surprisingly enough, they drown rather easily if water gets in the blowhole.

These are not only very speedy swimmers, but they are also very active ones. Their mammalian warm-bloodedness and efficient circulation accounts for this. Swimming in water takes great amounts of energy, so it is not surprising to find that the blood of dolphins can hold much more oxygen than that of land animals of equal size. Their sense of hearing is acute. They utter whistles, barks, and clucks through the blowhole and communicate by these means. They also whimper when injured.

Dolphins are much-fabled animals, long held in high esteem by sailors. This is not without reason, for dolphins are the known enemies of sharks. It is a bit hard to separate fact from fancy on this score, but dolphins have been reliably reported to attack both hammerhead and tiger sharks in the sea and in captivity. They harass sharks by punching them with their hard, bony snouts in a series

of swift, jolting blows. Sometimes several dolphins maneuver the shark into position so that another can strike a fatal blow in a tender spot like the region of the gills. Dolphins are also known to have pushed drowning people ashore, though stories of this sort are even more difficult to run down. The recognition of a person in distress would take a very high degree of intelligence; the pushing which we interpret as a rescue probably arises from the tendency of dolphins to push or nudge surface objects. For instance, they are known to give newborn young a push toward the surface to necessary air.

Most of what is known of dolphins is drawn from their behavior in captivity. There, these swift and extraordinarily playful creatures with the built-in grin are a constant source of amusement, taking well to captivity and their captors. Excepting the primates, their intelligence is perhaps greater than that of any other animal. Their brain is convoluted and a little heavier than man's. The highly developed brain of dolphins accounts for their elaborate play. For example, one poor pelican at Marineland in Florida was the object of frequent torment. One dolphin would pluck a feather from it, which it would toss about or try to balance on its nose as it swam. At other times, the bird would be the recipient of rather violent spanks from below, to its great consternation. Dolphins constantly nipped at the fishes in the tank and used to annoy a turtle by turning it repeatedly on its edge (Williams, 1950). The dolphin's play with people in the tank was well intentioned, but it tended to be a bit rough at times. Dolphins like to play catch. They will retrieve all sorts of objects, overshadowing retrieving dogs by throwing the object back. One dolphin, having received a somewhat overly dead mullet for food, threw it back, hitting an innocent lady bystander in the face.

Dolphins live for forty years or a little more. Much of their time is occupied with sex play, the ever-eager males seeming never to tire of chasing the females. The females in return, in heat only a few times a year, never seem to tire of eluding the males. The males form a hierarchy and fight among themselves for the female's attention. McBride and Hebb (1948) record several examples of the male's sexual ardor, one of which deserves mention. The penis "forms an efficient hook, and a young male was seen on several occasions to swim down at considerable speed, scoop up an eel at the bottom of the tank, and swim zig-zag all the way across the bottom of the tank with the eel wrapped about [it]."

When a female is giving birth, the normal companionship which dolphins show toward each other is accentuated. At such times, they band together and are alert, for the blood occuring at birth attracts sharks, which are driven away by these attendants.

Dolphins are truly masters of the seas, able to elude all pursuers except a member of their own family, the killer whale. Swimmers will have fascinating experiences with them under water and should carefully record what they see because little is known of them out of captivity. Dolphins will not usually flee a swimmer; in fact, they will often nudge a swimmer playfully.

COMMON DOLPHIN: *Delphinus delphis*

Size: Up to 8 feet or more.

Distribution: Cosmopolitan in warm temperate and tropical seas, chiefly offshore.

Identification: The beak is fairly long and separated from the low forehead by a groove. The back is almost black, and there are light markings of yellow and white on the sides.

Habits: It is like the common dolphin but is shier. This is the dolphin frequently seen at sea gamboling about ships' bows.

Similar Species: The little common porpoise (harbor porpoise), *Phocaena phocaena* (*fig. 196*), is a little, chiefly north temperate, coastwise species that reaches only about 6 feet and 120 pounds. It has no prolonged snout and is dark gray above and white below. It is very rare in the eastern United States being occasionally seen in Maine. It has been reported south to New Jersey in the Atlantic. More common on the Pacific coast, it also ranges farther south.

KILLER WHALE (GRAMPUS): *Orcinus orca*

Size: Males to 30 feet. Females one-half that size. The largest of the dolphins and porpoises.

Distribution: All seas, but most common in cold waters.

Identification: The very high, black dorsal fin is the best field character. The mouth is large and bears very heavy cutting teeth. The snout is rounded and not produced to form a beak. There are white marks above the eyes and the white of the belly extends up onto the sides.

Habits: The intelligence, speed, voracity, size, and power of these animals make them without doubt the most dangerous of all the sea's inhabitants. Luckily, they are not really common. They travel in small bands of two to three or even up to forty individuals and attack their prey cooperatively. The killer whale's favorite food is seal. Porpoises and the largest whales are also eaten. Its prey evidently must be moving to attract it. Sea otters are known to freeze in their presence to avoid detection. The high swordlike dorsal fin once gave them the name "swordfish" among some seafaring men. This name is now only used to mean certain fish, but old seamen's accounts of swordfish attacking baleen whales meant killer whales attacking baleen whales. The manner of hunting seals shows great cunning. Seals commonly bask on ice floes. The killer, spotting such a seal, will overturn the floe with its back and swallow the dislodged seal. Baby walruses, taking refuge on the backs of their mothers are also jarred loose and eaten. The remains of up to fourteen seals have been found in a single large killer's stomach. Killers have been known to break floes under men. One photographer, a member of the British antarctic Terra Nova Expedition barely escaped with his life as a floe was shattered by killers just as he ran to safety. The attacks on whales are even more spectacular and cunning. Several killers will hold the flippers of a large baleen whale while others tear juicy hunks out of the tender lips and tongue. This frequently kills the large whale. It is said that California gray whales become literally petrified in the killers' presence, lying on their backs, tongues out, awaiting their fate. Some reports also say that killers are able to use the high dorsal fin as a weapon. The authors do not know about the truth of this statement. It is hard to say what a diver should do in the presence of a band of killers. Freezing motionless, an action that would probably be involuntary anyway, might be attempted—after you have taken a picture, of course.

BIBLIOGRAPHY

Following is a list of works cited as well as recommended works for further reference. Those considered by the authors to be particularly useful are marked with an asterisk (*).

CHAPTERS 1 AND 2: ECOLOGY

*W. C. Allee, A. E. Emerson, O. Park, T. Park, and K. P. Schmidt
1950 *Principles of Animal Ecology*. Saunders, Phildelphia.

Barnett, Lincoln
1953 "The miracle of the sea." Part II of *The World We Live In*. Life Magazine, February 9: 74–94.

———
1953 "Creatures of the sea." Part VII of *The World We Live In*. Life Magazine, November 30: 79–108.

———
1954 "The coral reef." Part VIII of *The World We Live In*. Life Magazine, February 8: 58–82.

*Carson, Rachel
1951 *The Sea Around Us*. Oxford University Press, New York.

*Cott, H. B.
1940 *Adaptive Coloration in Animals*. Methuen, London.

J. Y. Cousteau
1954 "To the depths of the sea by bathyscaphe." National Geographic Magazine, July: 67–79.

*Elkman, Sven
1954 *Zoogeography of the Sea*. Sidgwick and Jackson, London.

*Elton, Charles
1935 *Animal Ecology*. Sidgwick and Jackson, London.

Hardy, A. C.
1953 "Some problems of pelagic life." In *Essays in Marine Biology*. Oliver and Boyd, Edinburgh.

*Hesse, R., W. C. Allee, and K. P. Schmidt
1951 *Ecological Animal Geography*. Wiley, New York.

Jarmer, K.
1928 "Das Seelenleben der Fische." München, Berlin, Oldenbourg.

Lehrman, D. S.
1953 "A critique of Konrad Lorenz's theory of instinctive behavior." Quart. Rev. Biol. 28: 337–363.

*MacGinitie, G. E. and N. MacGinitie
1949 *Natural History of Marine Animals*. McGraw-Hill, New York.

McDougall, W. B.
1918 "The classification of symbiotic phenomena." Plant World, 21: 250–256.

*Marshall, N. B.
1954 *Aspects of Deep Sea Biology*. Philosophical Library, New York.

Marshall, S. M. and A. P. Orr
1953 "The production of animal plankton in the sea." In *Essays in Marine Biology*. Oliver and Boyd, Edinburgh.

Odum, E. P.
1953 *Fundamentals of Ecology*. Saunders, Philadelphia.

*Russell, F. S. and C. M. Yonge
1928 *The Seas.* Warne, London.
*Sverdrup, H. U., M. W. Jackson, and R. H. Fleming
1942 *The Oceans.* Prentice-Hall, New York.
Verrier, M. L.
1928 "Recherches sur les yeux et la vision des poissons." Bull. Biol. Fr. et Belg. Presses Universitaires de France. Supplement XI: 230.

CHAPTERS 3 AND 4: MAN AND THE SEA

*Carrier, R. and B. Carrier
1955 *Dive.* Funk, New York.
*Cousteau, J. Y.
1953 *The Silent World.* Harper, New York.
*Phillips, C. and W. H. Brady
1953 *Sea Pests.* University of Miami Marine Laboratory. University of Miami Press.
*Schenck, H., Jr., and H. Kendall
1954 *Underwater Photography.* Cornell Maritime Press, Cambridge, Maryland.
*Schenck, H., Jr., and H. Kendall
1954 *Shallow Water Diving and Spearfishing.* Cornell Maritime Press, Cambridge, Maryland.

CHAPTER 5: EVOLUTION

*Dobzhansky, T.
1951 *Genetics and the Origin of Species.* Columbia University Press, New York.
*Mayr, E.
1942 *Systematics and the Origin of Species.* Columbia University Press, New York.
Romer, A. S.
1945 *Vertebrate Paleontology.* University of Chicago Press, Chicago.
*Simpson, G. G.
1953 *Major Features of Evolution.* Columbia University Press, New York.
*Simpson, G. G.
1949 *The Meaning of Evolution.* Yale University Press, New Haven.
Schenk, E. T. and J. H. McMasters
1948 *Procedure in Taxonomy.* Stanford University Press, Stanford, California.
Twenhofel, W. H. and R. R. Shrock
1935 *Invertebrate Paleontology.* McGraw-Hill, New York.

CHAPTER 6: PLANTS

Blinks, L. R.
1954 "The role of accessory pigments in photosynthesis." In *Autotrophic Microorganisms,* Ed. by B. A. Fry and J. L. Peel. Cambridge University Press.
*Smith, G. M.
1944 *Marine Algae of the Monterey Peninsula, California.* Stanford University Press, Stanford, California.
*Taylor, W. R.
1937 *Marine Algae of the Northeastern Coast of North America.* University of Michigan Press, Ann Arbor, Michigan.

CHAPTER 7: INVERTEBRATES

*Abbott, R. T.
1954 *American Seashells.* Van Nostrand, New York.

*Borradaile, L. A. and F. A. Potts
1935 *The Invertebrata.* Macmillan, New York.
*Buchsbaum, R.
1948 *Animals Without Backbones.* University of Chicago Press, Chicago.
*Hyman, L. H.
1940 *The Invertebrates.* Vol. 1. Protozoa through Ctenophora. McGraw-Hill, New York.
1951 Vol. 2. Platyhelminthes and Rhynchocoela. The acoelomate Bilateria.
1951 Vol. 3. Acanthocephala, Aschelminthes, and Entoprocta. The Pseudocoelomate Bilateria.
1955 Vol. 4. Echinodermata.
Continuing volumes to be published.
Klingel, G. C.
1944 "In defense of octopuses." In *The Book of Naturalists,* Ed. by William Beebe. Knopf, New York.
*Mayer, A. G.
1910 *Medusae of the World.* Carnegie Institute of Washington, Washington, D.C.
*Mayer, A. G.
1912 *Ctenophores of the Atlantic Coast of North America.* Carnegie Institute of Washington, Washington, D.C.
McGowan, J. A.
1954 "Observations on the sexual behavior and spawning of the squid, *Loligo opalescens,* at La Jolla, California." Calif. Fish and Game, 40: 47–54.
*Miner, R. W.
1950 *Field Book of Shore Life.* Putnam's, New York.
*Parker, T. J. and W. A. Haswell
1947 *A Text-book of Zoology.* Volume I, 6th edition. MacMillan, London.
*Ricketts, E. F. and J. Calvin
1952 *Between Pacific Tides.* 3rd edition revised by J. W. Hedgpeth. Stanford University Press, Stanford, California.
Thompson, Sir C. W. and J. Murray
1887 *Report on the Scientific Results of the Voyage of H. M. S. Challenger.* Publ. by order of Her Majesty's Government, Edinburgh.
*Young, J. Z.
1950 *The Life of Vertebrates.* Chaps. 2 and 3. Clarendon Press, Oxford.
Zim, H. S. and L. Ingle
1955 *Seashores.* Golden Nature Guide. Simon and Schuster, New York.

CHAPTERS 8 AND 9: FISHES

*Ackerman, Bill
1951 *Handbook of Fishes of the Atlantic Seaboard.* American Publishing Co., Washington, D.C.
Anglo-American Caribbean Commission
1945 *Guide to Commercial Shark Fishing in the Caribbean Area.* Kaufman, Washington, D.C.
Aronson, L. R.
1951 "Orientation and jumping behavior in the gobiid fish, *Bathygobius soporator.*" Amer. Mus. Novitates no. 1486.
*Barnhart, P. S.
1936 *Marine Fishes of Southern California.* University of California Press, Berkeley, California.

*Beebe, W. and J. Tee-Van
1928 *The Fishes of Port-au-Prince, Haiti.* Zoologica X: 1–279.
*Beebe, W. and J. Tee-Van
1933 *Field Book of the Shore Fishes of Bermuda.* Putnam's, New York.
Bertin, L.
1942 *Les Anguilles.* Payot, Paris.
*Bigelow, H. B. and W. C. Schroeder
1948 *Fishes of the Western North Atlantic.* Vol. I. Lancets, Cyclostomes, and Sharks. Mem. Sears Foundation for Marine Research, Yale University.
1955 Vol. II. Sawfishes, Guitarfishes, Skates, and Rays.
*Breder, C. M., Jr.
1926 "The locomotion of fishes." Zoologica 4: 159–297.

———
1938 A contribution to the life histories of Atlantic Ocean flying fishes." Bull. Bingham Oceanographic Coll. Peabody Mus. Nat. Hist., Yale University. VI, Art. 5.
*———
1948 *Field Book of Marine Fishes of the Atlantic Coast.* Putnam's, New York.
Breder, C. M., Jr. and C. W. Coates
1933 "Reproduction and eggs of *Pomacentrus leucoris* Gilbert." Amer. Mus. Novitates no. 612.
Breder, C. M., Jr. and H. E. Edgerton
1942 "An analysis of the locomotion of the seahorse, *Hippocampus,* by means of high speed cinematography." Ann. N. Y. Acad. Sci. 43: 145–172.

———
1946 "Do flying fishes really fly?" Travel and Camera, August: 73–76.
Briggs, J. C.
1955 "A monograph of the clingfishes (Order Xenopterygii)." Stanford Ich. Bull. Nat. Hist. Mus., Stanford University. Vol. 6.
*Budker, P.
1947 *La Vie des Requins.* Gallimard, Paris.
Coles, R. J.
1916 "Natural history notes on the devilfish, *Manta birostris* (Walbaum) and *Mobula olfersi* (Müller)." Bull. Amer. Mus. Nat. Hist. 35: 649–658.
Crawford, R. W. and C. F. Powers
1953 "Schooling of the orange filefish, *Alutera schoepfi,* in New York Bight." Copeia: 115–116.
*de Latil, P.
1955 *The Underwater Naturalist.* Houghton-Mifflin, Cambridge, Mass.
De Witt, J. W.
1955 "A record of an attack by a leopard shark (*Triakis semifasciata*)." Calif. Fish and Game 41: 348.
Fast, T. N.
1955 "Second known shark attack on a swimmer in Monterey Bay." Calif. Fish and Game 41: 348–351.
Gill, T. N.
1907 "Life histories of toadfishes (Batrachoidids) compared with those of weavers (Trachinids) and stargazers (Uranoscopids)." Smithsonian Misc. Coll. 48: 388–427.

———
1908 "Angler fishes; their kinds and ways." Smithsonian Report no. 1907: 565–615.
*Gray, J.
1953 "The locomotion of fishes." In *Essays in Marine Biology.* Oliver and Boyd, Edinburgh.

Gudger, E. W.
1932 "Cannibalism in sharks and rays." Sci. Monthly 34: 403–419.

*Harris, J. E.
1953 "Fin patterns and mode of life in fishes." In *Essays in Marine Biology*. Oliver and Boyd, Edinburgh.

Herald, E. S.
1953 "Spotted cusk eel, the strange fish that stands on its tail." Calif. Fish and Game 39: 381–384.

*Jordan, D. S.
1905 *A Guide to the Study of Fishes*. Holt, New York.

*Jordan, D. S. and B. W. Evermann
1900 *The Fishes of North and Middle America*. Bull. U.S. Nat. Mus. no. 47, Washington, D.C.

*———
1908 *American Food and Game Fishes*. Doubleday-Page, New York.

*La Monte, F.
1946 *North American Game Fishes*. Doubleday, New York.

Ley, Willy
1951 "The story of the fish *Anguilla*." In *Dragons in Amber*. Viking Press, New York.

Linton, E.
1907 "Notes on the habits of *Fierasfer affinis*." Amer. Naturalist 41: 1–4.

*Longley, W. H. and S. F. Hildebrand
1941 *Systematic Catalogue of the Fishes of Tortugas, Florida*. Carnegie Institute of Washington, Publ. 535.

*Norman, J. R.
1931 *A History of Fishes*. Benn, London.

*Norman, J. R. and F. C. Fraser
1938 *Giant Fishes, Whales and Dolphins*. Norton, New York.

Orcutt, H. G.
1950 "The life history of the starry flounder, *Platichthys stellatus* (Pallas)." Calif. Dept. Nat. Res., Div. Fish and Game, Fish Bull. no. 78.

Phillips, C.
1952 "An observation of flight in the pompano." Copeia: 203.

*Roedel, P. M. and W. E. Ripley
1950 *California Sharks and Rays*. Calif. Dept. Nat. Res., Div. Fish and Game, Fish Bull. no. 75.

Smith, J. L. B.
1951 "A case of poisoning by the stonefish, *Synanceja verrucosa*." Copeia: 207–210.

*Springer, S.
1943 "Sharks and their behavior with particular reference to eight genera implicated in reports of attacks on man." Coordinator of Res. & Dev., USN Emergency Rescue Equipment Section.

Tavolga, W. N.
1954 "Reproductive behavior in the Gobiid fish, *Bathygobius soporator*." Bull. Amer. Mus. Nat. Hist. 104: 427–460.

Townsend, C. H.
1929 *Records of changes in color among fishes*. N. Y. Zool. Soc.

Walford, L. A.
1937 *Marine Game Fishes of the Pacific Coast from Alaska to the Equator*. University of California Press, Berkeley, California.

*Young, J. Z.
1950 *The Life of Vertebrates.* Clarendon Press, Oxford.

CHAPTER 10: THE RE-ENTRANTS

*Anthony, H. E.
1928 *Field Book of North American Mammals.* Putnam's, New York.
*Carr, A.
1952 *Handbook of Turtles.* Comstock, Ithaca, New York.
Carr, A.
1955 "The riddle of the ridley." Animal Kingdom LVIII: 146–156. Reprinted from *The Windward Road* by Archie Carr, Knopf, 1955.
McBride, A. F. and D. O. Hebb
1948 "Behavior of the captive bottle-nose dolphin, *Tursiops* truncatus." Jour. Comp. Physiol. Psych. 41: 111–123.
*Norman, J. R. and F. C. Fraser
1938 *Giant Fishes, Whales and Dolphins.* Norton, New York.
*Peterson, R. T.
1941 *A Field Guide to Western Birds.* Houghton Mifflin, Boston.
*———
1947 *A Field Guide to the Birds.* Houghton Mifflin, Boston.
*Pettingill, O. S.
1953 *A Guide to Bird Finding.* Oxford, New York.
*Pope, C. H.
1949 *Turtles of the United States and Canada.* Knopf, New York.
*Pope, C. H.
1955 *The Reptile World.* Knopf, New York.
*Pough, R. H.
1953 *Audubon Guides: All the Birds of Eastern and Central North America.* Doubleday, Garden City, New York.
*Schmidt, K. P. and D. D. Davis
1941 *Field Book of Snakes of the United States and Canada.* Putnam's, New York.
Seton, E. T.
1953 *Lives of Game Animals.* For sea otter, see Volume II, Part II. Reissued from 1923 edition. C. T. Branford, Boston.
Williams, G.
1950 "Practical joker of the high seas." Saturday Evening Post, October 7: 32–33, 169–172.

INDEX

Reference to page numbers for figures is made in italics. Reference to color plates is made in text under each species. Because of space restrictions, reference to group and some species names have been omitted as in the following cases:

Example a Family Rachicentridae would be given by type genus *Rachycentron.*

Example b The red, black, and broom-tail groupers are indicated simply by the word "grouper."

Example c All species of the genus *Acropora* (e.g. *cervicornis, palmata*) are referred to by the genus name only.

abalone 21, *120,* 121
Abudefduf 253
abyssal zone *10,* 18–20
Acanthocybium 210
Acanthurus 265
Achirus 298, 299
Acipenser 180
Acropora 24, *102,* 103
Adamsia 103, *114*
adaptation (see evolution 68–73) 27–29
adaptive radiation 71
advertisement 43–45, 262, 302
Aerosoma 128, 129
Aetobates 139–173
Agardhiella 85, 116
Agarum 82, 83
Agnatha 132–135
Alaria 80, 83
albacore 210, 211
Albula 183
Alcidae 309
Alcyonium 96, 103
Alectis 219
alewife 216, 217
algae 16, 17, 23, 76–85, *79, 81, 82, 84*
allmouth 300
Alopias 151
Alosa 185
Alphestes 230
alteration of generations 94, *95*
Alutera 267, 268, *268*
ambergris 318
amberjack 213, 214
a-mi-kuk 310
Ammocoetes 133
Ammodytus 206
Amoeba 87
Amphineura 119–121
Amphinomidae 109
Amphioplus 128
Amphioxus 21, 130, *131*
amphipod 116
Amphistichus 252
Anacanthini 284, 292–294
anatomy, bony fish *178;* shark and ray *136*
Anarhichas 289
Anchoviella 186
anchovy, striped 186, *186*
anemone 21, 38, 44, 47, 53, 63, 100–104, 119
angelfish 34, 44, 64, 261–265, *264*
Angelichthys 263
angler 21, 39, 40, 41, 44, 45, 299–302, *300*
Anguilla 191
Anistotremus 241, 242
Annelida 48, 107–111
Anomia 123, 124
Anseridae 309
Antedon 128, 130
Antennárius 301
Antherinidae 186, 202–203
Anthozoa 100–104
Aphrodite 108, 109
Aplysia 40, 44, 122
Apodes 73, 180, 190–195
Apogonichthys 223
Arachnida 117
Arbacia 128
Arca 123, 124
Architectonia 120
Architeuthis 125
Archosargus 244
arctic *15,* 17
Arenicola 108, 111
Argentinidae 188
Argonauta 123, 125–126
Arthropoda 49, 107, 111–119
Ascophyllum 80
Astarte 123
Asterias 128
Asterida 127
Astrangia 96, 103
Astrea 120
Astroscopus 283
Athecae 307
Aulostoma 193, 200
Aurelia 96, 99
Autolytus 109
autotomy 44–45, 112, 127
Auxis 209
Aves 309
avicularia 106, 107
awa 184
Ayresia 254

bacteria 3, 5, 36, *36*
Bagre 195
bagre sapo 285
Bairdella 247
Balaena 317
Balaenoptera 316
Balanoglossus 130, *131*
Balanus 113, 115
Balenophylla 96, 104
Balistes 266

banana fish 183
barbero 265
barnacle 21, 23, 32, 38, *113*, 115
Barnea 123, 124
barracuda 40, 51, 65, 204, 205, *205*
barriers to dispersal 27, 32
bass 223–234; black sea 226, *226;* blue and gold fairy 234; California kelp 225; California white sea 248; channel *248*, 249; Gulf sea 226; midget 233, *233;* rock 225; shortfin sea 248; silver 225; spotted kelp *226;* striped 34, 35, *224*, 225
batfish 41, 44, 302, *302*
Bathygobius 280
Bathystoma 239, 240
Batrachoididae 284–285
baya 229
Bdellostoma 135
Bdelloura 105, *105*
beau gregory 253
bêche-de-mer *129*, 130, 291
behavior 46–52
Belonidae 197–198
benthic subprovince *10*, 18, 19–22
bergall 256
Berycoidei 207–208
big-eye 7, 234–235
billfish 197–198
bioluminescence 8, 88, 104, 111, 125, 131, 300
birds 309
blackfish 255
blacksmith 254
blanquillo 282–283
Blennius 287
blenny 17, 21, 32, 34, 39, 287, 288, *288*
blood 65, 86, 106, 142
bluefish 52, *218*, 219
blue-head *102*, 257
boccacio 273
Bodianus 257
bonaci 229
bonefish 40, *182*, 183
Bonellia 111
bonito 199, 210, 214
bore, tidal 12
boreal seas *15*, 17
Bossea 84, 85
Boston blackfish 293
boxfish 64, 271
Branchiocerianthus 95
Brachiopoda 18, *123*, 126
Brachydeuterus 240
Brama 222
bream 240, 245, *245*
Brevoortia 185
brim 244
Bryopsis 78, *79*
Bryozoa 18, 21, 23, 106–107, *106*
bug, sand *114*, 116–117
Bugula 106, 107
Bulla 120
bumper 216
buoyancy (see flotation and support) 2, 6
burbot 294
burro 240
Busycon 120, 121
butterfish 221, *222*
butterfly fish 39, 40, 43, 44, 68–73, 261–262

cabezone 276
cabrilla 225, 229, 231
cachelot 318
caesar 239, *239*
Calamus 243, 244
Calanus 113, 115
Calappa 114
Calcarea 91–92
calcium 4, 23
Calliostoma 120
Callorhinus 312
Cancer 114
Canthidermis 264, 267
Canthigaster 271
canyon, oceanic 10, *10*
capitan 256
Caprella 113, 116
Carangidae 213–219
Caranx 205, 215, 216
carbon dioxide 5
Carcharias 141, 147
Carcharinus 138, 141, 155, 156
Carcharodon 140, 148
cardinal fishes 222–223
Cardium 123
Caretta 306
Carnivora 309–314
carnivore 33, 34, 309–310
carrying capacity 33
Carybdea 96, 99
Cassiopeia 96, 100
Cassis 121
catalufa 234
catfish 64, *194*, 195–196, *196*
cavalla 210
Caulolatilus 283
Centropomus 223
Centropristes 226
Cephalochordata 130
Cephalopholis 231, 232
Cephalopoda 125–126
Cephaloscyllium 146
Ceratium 88, *88*
Cerebratulus 105, 106
cero 210
Cestus 104, *104*
Cetacea 315–321
Cetorhinus 149
Chaetodipterus 261
Chaetodon 262
Chaetognatha 106
Chaetopterus 108, 111
Chalina 91, 93
Challenger 123
Chanos 184
characin 195
Cheilodipteridae 222–223
Chelonia 302–308
Chelonia 305
cherna 230
chien de mer 154
Chilomycterus 271
chimaera 63, 64, 176
Chimaera 176
chirivita 263
chiro 182
chiton 119–121, *120*
Chloroscombrus 216
Chondrus 84, 85
chopa 246
Chorda 84, 85
Chromides 252–254
Chromis 254, *255*
Chrondrostei 179–180
chrysomonad 88, *88*
chub, Bermuda 246
ciguatera 236, 266
Ciliata *88*, 89–90
Ciona 131, *131*
Cirripedia 115
Citharichthys 297
Cladocera 113

Cladophora 78, *79*
clam 18, 21, 48, 49, 64, *123*, 124
clamacore 259
classification 73–75
cling fish 285–286
Clinocottus 277
Cliona 93
Clionopsis 123
Clupea 184, 185
cobia 44, 220, *220*
cocino 266
cockeye pilot 253
cod 17, 292–294, *293*
Codium 79, 80
Coelenterata 47, 63, 93–104
Colobus 198
color 7, 25; and depth 8, 40, 54
coloration, adaptive 39–46, *41*, *42*, 262
color change 39, 40, 125, 179, 280, 287
Colymbidae 309
commensalism 38, 105, 118
community 15, 28, 30
competition 19, 25, 27
conch 121
conchfish 7, 121, 223
coney 231
conservation (see introduction) 304, 310–311, 316
continental shelf 9, *10*, 20; slope 9, *10*
Conus 122
convergence 71
convict fish 276, *276*
Convoluta 105, *105*
Copepoda 18, *113*, 115
coral 4, 23–25, 30, 32, 63, 95, *96*, *97*, 100, *101*, *102*, 104, *255*
Corallina 84, 85
Corallium 100, 102
corbina 248, 250, 251
cornet fish 201
coronado 213
Coryphaena 199, 221, 318
Cottus 276
cowfish 40, *42*, 269
cowrie 121
crab 22, 23, 38–39, 41, 45, 72, 91, 95, 103, 105, *110*, *113*, *114*, 117, 118, *118*
crab-eater 220
crampfish 168
Crangon 114, 117
Craniomi 278–279
crayfish 72
Crepidula 120, 121
creole fish, southern 232, *232*
Cribina 103
croaker 66, 246–251
Crustacea 19, 20, 21, 22, 44–45, 49, 112–117
Cryptocanthodes 289
Cryptochiton 121
cryptomonad 88, *88*
Ctenodiscus 128
Ctenophora 104
cubbyu 251
cubby yew 220
cubomedusan 99
Cucumaria 128
cucuyo 266
cultus cod 276
cunner 256
currents 12–14, *13*, 16, 32
cusk 294
cusk eel 290–291
cutlass fish 211, *211*
cuttlebone 125
cuttlefish 44, 125
Cuvierina 123
Cyanea 19, 99
Cyanophyta 78
Cyclops 115
Cyclostomata 133
Cynoscion 247, 248
Cyphoma 120
Cypraea 121
Cyprinodontidae 196–197

Dactylometra 96, 99
Dactylopterus 279
Dalatiidae 160
Daphnia 113
Dasyatis 139, *162*, *170*, 171, 172
dead man's fingers *96*, 103
decapods 116–117
Decapterus 215
deep scattering layer (DSL) 35, *36*
deep sea bottom 10, *10*
Delphinus 319, 320
demoiselle 43, 252–254
Demospongiae 93
Dentalium 120
dentex 243
depth 6–7; and body form 11, 19–20
dermal denticle 136
Dermochelidae 307–308
Desmarestia 80, *80*
devilfish *174*, 175–176
devil's apron *82*, 83
diablo 302
Diadema 127, *128*
diatom 18, 19, 20, *77*, 77–78
dinoflagellate 88
Diodon 271
Diplectrum 233, *233*, 234
Diplodus 245
Discocephali 282
discomedusan 99
disguise 45
dispersal 30–33
distribution *30*, 30–33
doctorfish 265
dogfish 64, 146, 151, 159, *159*
Doliolum 131
dollarfish 221
dolphin 199, *220*, 221, 309, 315, 318–321, *319*
dorado 221
Dormitator 281
drum, black 249, *249*
dugong 314
dulse *84*, 85
Dunaliella 78, *79*, 87

Echeneis 282
Echinocardium 128
Echinodermata 18, 47, 126–130
Echiurus 108, 111
ecology, definition of 1
Ectocarpus 80, *82*
eel 16, 22, 65, 190–195; rock 17, 288; slime 134; wolf 290
eelgrass 22, 76, 85, 305
eelpout 290, *291*
Elagatis 214
electric shock 166, 167, 283
Electrophorus 167
Elops 182
Embiotocidae 252
Emmydrichthys 272
Engraulidae 186–187
Enhydra 310
enjambre 232
Ensis 125, 124
Enteromorpha 78, *79*

Entosphenus 134
Eolis 122
Ephippidae 261
Epinephelus 42, 227, 228, 230, 231
Epitonium 120
Eques 42, 251
Eretmochelys 305
Eschrichtius 317
escolar 64
Eubalaena 317
Eucinostomus 246
Euglenophyta 77
Eumetopias 313
Eunice 108, 109
euphausians *113,* 116
Euplectella 91, 93
European weaver 44, 45
Eurythoë 109
Eusmilia 101, 103
Euspongia 90, *91,* 93
Evadne 113
evolution 27, 38, 68–73, *69, 75,* 132–133, 161–162
Exocoetidae 199
eye 8, 49, 112, 125, 138; camouflage 41, 70, 262

Fasciolaria 120
fatback 204
features of the sea 9, 10, *10*
feeding mood 65, 140, 142
feeder, chemical 52; filter 34; visual 52
Fibula 93
Fierasfer 291
filefish 45, 64, 267–268, *268*
fins, bony fish 177–178, *178;* shark and ray *136,* 138
fishes of the king 203
fishing frog 299, 300
fish lice 115
Fistularia 201
Flagellata 77, 87–89
flatfish 21, 40, 41, 294–299
flatworms 104–105
flea, beach 116; sand *113,* 116; water, 113, *113*
flight (see synentognaths 197–199) 217, 278
flotation 4, 9, 19
flounder 295–298, *297*
fluke, blood 63, 104; northern 296, *296*
flying fish 40, 199
flying gurnard 279, *279*
food chain 28, 33–37, *36, 37*
foraminiferans 23, 89
frogfish 301
fry, green *186,* 187, 202
Fucinus 120
Fucus 21, 80, *82*
Fundulus 197

Gadus 293
gag 229
Galeichthys 195
Galeocerda 137, 140, 141, 153
Galeoidea 145–159
Galeorhinus 157
gambuso 156
Gammarus 113, 116
gar 197–198
garibaldi 253
Garrupa 227
gases in sea 4–5
Gasterosteus 200
Gastropelecus 199
Gastropoda 121–122
gata 145
Gaviidae 309
gene 68–69
Genyonemus 249, 250
Germo 210
Gerres 245
Geryonia 97
ghost fish 183
Gigartina 84, 85
Ginglymostoma 137, 145
Girella 246
glass-eye 235
Globigerina 19, *88,* 89
goatfish 207, 208
Gobiesox 286
Gobiidae 21, 39, 279–281
Gonionemus 96
Gonyaulax 88, *88*
Gorgoncephalus 103, 127, *128*
Gorgonia 101, 102
gorgonian 45, *97, 98,* 100–104, 102, 127, *193, 255, 264*
Gramma 234
grampus 321
grande ecaille 181
Grantia 91, 92
grayfish 159
graysby 232
greenfish 246
greenling 17, 275–276, *275*
grouper 41, *42,* 66, 228–232
growth and adaptation 29
grunion 203
grunt 32, 66, 72, 238–242, *241*
guacamaia 259
guaguanche 204
guitar fish 164–165, *165*
Gulf Stream 14, 22, 24
gunnel 288
Gymnodinium 88
Gymnodontes 266
Gymnogongrus 84, 85
Gymnothorax 73, 74, 194
Gymnura 172

haddock 293
Haemulon 32, 240, *241*
hagfish *134,* 135
hake 292
halfbeak 198–199
halfmoon, California 246
halibut 17, 295, *295,* 296
Halichoerus 313
Halichondria 91, 93
Halicystis 96
Halimeda 23, *79,* 80
Haliotis 120
Halobates 118, 119
hamlet 230
Haplodoci 284–285
Haplomi 196–197
hardhead 250
harlequin serranid *42,* 233
harvest fishes 221–222
hatchet fish 199
hearing (see behavior 46–52)
hectocotylus *123,* 126
Hemibranchi 199–201
Hemichordata 130
Hemirhamphidae 198–199
Hemitripterus 277
Henricia 128
Heptranchus 145
herbivore 8, 33, 35, 310
hermaphroditism, barnacles 115
Hermodice 108, 109
herring 17, 34, 35, 72, 184–187, *184*
Heterodontidae 143–144
Heterosomata 294–299

Heterostichus 287
Hexactinellida 93
Hexagrammos 275, 276
Hexanchus 144
hind 231
Hippa 21, *114*, 116, 164
Hippocampus 201
Hippoglossus 295, 296
Hircina 92, 93
Histrio 301
hogfish 256, 257
Holconoti 251–252
Holocanthus 262, 263
Holocentrus 207
Holocephali 176
Holothuria 128, *129*, 130
Homarus 117
Hoplopagrus 238, *238*
horsehead 218
horse latitudes 12
houndfish 198
Hydractina 95, *114*
hydrogen sulfide 5
hydroids 21, 23, 63, 94–95, *98*, 118, 122
Hydrolagus 176
Hydrophidae 308–309
Hydrozoa 94
Hynnis 217
Hypomesus 189
Hypoplecturus 233
Hypoprion 141, 155
Hyporhamphus 198
Hypotremata 161–176
Hypsypops 253

ichthyocism 205
inflation 146, 277
Iniomi 189
Insecta 119
instinct 47
invertebrate, definition 86
Iridio 257–258
Irish moss *84*, 85
isabelita 263
isolation 27
isopods 116
Isospondyli 180–190
Istiophorus 212
Isurus 141, 147

jack 213–219
jaqueta 253
jellyfish 2, 18, 19, 20, 63, 94, *96*, 99, 104, 131
Jenkensia 186, 187
jewelfish 253
jewfish 29, 65, 66, 226–228, *227*, *228*
jocu 236
john-paw 231
jugular fishes 284–294
jumper 204

kalan 310
Katsuwonus 199, 211, 210
kelp 64, *80*, *82*, 83
kelp basses 16, 225–226
killifish 21, 22, 30, 196–197, *197*
kingfish 210, 250
krill 34, 112–113, *113*, 116
Kyphosus 246

Labroid fishes 254–260
Lachnolaimus 256
Lactophrys 42, 269, *269*, *270*
ladyfish 40, 182, 183
Lagocephalus 270
Lagodon 245
Laminaria 82, 83
Lamna 148
lampreys 133–134, *134*
langouste 72
lateral line *48*, 50, 65
laver *84*, 85
law of the minimum 31, *31*
leatherjacket 213, *213*
Leiostomus 249, 250
Lepas 113, 115
Lepidochelys 307
Lepidonotus 108, 109
leptocephalus 191, 192
Leptocephalus 192
Leptosynapta 128
Lessionopsis 80, 83
Leucifer *114*
Leucoselenia 91, 92
Leuresthes 203
Libinia 114
life, abundance of 4, 13, 17, 18, 35, 36, *36*, 316; diversity of 27; origin of 26–27
Ligia 113
light 6–8, 18, 20, 31, 35, 39, 53–54, 58–59
limiting factors 6, 23–25, 30–31, *31*, 32, 33
limpet *120*, 121
Limulus 105, 118, *118*
ling, squirrel 294, *294*
ling cod 276
Lingula 72, *123*, 126
lionfish 272, 274
Littorina 120, 121
lizard fish 189–190
Lobotes 234
lobster 72, *114*, 117
locomotion (see movement)
Loligo 123, 125, 126
lookdown 218
Lophias 45, 300
Lophiomus 301
Lophobranchi 201–202
Lopholatilus 283
Loricati 271–277
loro 258, 259
Lutianus 236, 237
Lytocarpus 95, *96*

machete 211
mackerel 32, 40, 41, 43, 72, 208–211, 215, 220
Macrocystis 82, 83
mail-cheeked fishes 271–277
Makaira 212
maki-maki 64, 266
Malacanthus 282
Malacostraca 116
Mammalia 18, 309–321
manatee 16, 309, 315
mangrove 22
man-of-war fish 38, 43, 220–221
Manta 175
mapo 280
margate 73, 240, 242
marlin 212
marsh grass 21
Mastigophora 77, 87–89
Meandra 102, 103
Medialuna 246
medico 265
medusas 93–104, *96*
Megalopidae 181–182
Megaptera 317
Melanogrammus 293
Mellita 128

menhaden 185, *186*
Menidia 203
Menticirrhus 247, 250, 251
Merluccius 292
mermaid's fish line *82*, 83
merman's shaving brush *79*, 80, *129*
Mesichthys 180–181, 196–202
Metacrinus 128
Metridium 96, 103
Microciona 91, 93
Microgadus 293, 294
Micropogon 249, 250
Microspathodon 254
midshipman 285, *285*
milkfish 183–184, *183*
Millepora 95, *97*, *255*
miller's thumb 276
mimicry 45–46
Mirounga 314
Mnemiopsis 121
Mobula 175
mojarra 73, 241, 245–246, *245*
Molgula 131, *131*
Mollusca 22, 48–49, 119–126
molly miller 280, 287
Monachus 314
monkfish 160, 161, *161*, 300
Monocanthus 268
moonfish 218
Morone 225
moss animal 106–107
moss-bunker 185
mountains, oceanic 10, *10*
movements, bony fish 177–179; and chumming 67; invertebrate 46–49, 86–131; shark and ray 138–139, 161–162
mud-belly 259
mud line 22
Mugil 204
mullet 35, 36, 184, 204, *204*
Mullus 208
Muraenidae 73, 193–195
Murex 120, 121
mussel 21, *123*, 124
Mustelus 152
mutation 69–70
muttonfish 236
mutualism 38–39, 91, 95
Mya 124
Mycteroperca 229, 230
Myliobatis 174
Myoxocephalus 277
Mysticeti 316–317
Mytilus 123, 124
Myxine 135

Nassa 120, 121
Natica 120, 121
natural selection 70
Naucrates 214
nauplius 112, *113*
nautilus, chambered 19
Nebalia 113, 116
needlefish 197–198
nekton 18, 32
Nematistius 219
nematocyst 63, 94, *95*, 99, 100, 103, 122
Nemertea *105*, 106
Neothunnus 210
Neptune's cup 91
Nereis 48, *48*, 63, 107, *108*, 109
Nereocystis 82, 83
Nerita 120
neritic province *10*, 20–22
nerve fiber, giant 125
nervous system (see behavior 46–52) *48*, 93–94, 132
niche 28, 33
nictitating membrane 152
nitrogen 3
Noctiluca 88, *88*
nohu, black 272
Nomeus 220
Notidanoidea 144–145
Noturus 195
nudibranch 91, 122
nuisance 253
numbers, and deep sea 35, 36, *36;* of individuals 27, 33, 36; pyramid of 36, *37;* of species 27; and temperature 17
numbfish 168
Nymphon 118

oarfish 19
Obelia 95, *96*
oceanic province *10*, 18–20
ocean sunfish 19
ocellus 48
octopus 18, 21, 39, 40, 43, 44, 48, 49, 63, 66, 100, 125–126
Ocyurus 208, 237
Odontoceti 317–321
Ogcocephalus 302
oldwife 216, 259, 266
olfactory sense, fishes *48*, 50, 140
Oligoplites 213
Oliva 120
omnivore 33, 34, 310
Oncorhynchus 187, 188
ooze 9, 19, 89, 122
opaleye 246
Ophichthys 192, *193*
Ophidioidei 284, 290–291
Ophiodon 276
Ophiurida 127
Opsanus 284
Orcinus 321
Oreaster 127, *129*
Orthopristes 242
Osmerus 189
Ostariophysi 180, 195–196
Osteichthyes 73
Ostracion 270
Ostracoda 113, *113*
Ostracodermi 266
Ostrea 123, 124
Otariidae 311–313
Otophidium 291
oviparous 139
ovoviviparous 139
oxygen 4–5
Oxylebius 276
Oxyulis 257
oyster 18, 22, 31, 48, 64, 72, *123*, 124
oyster drill *120*, 121
oysterfish 255

Padina 82, 83
paguala 261
Pagurus 114
palometa 216, *217*
Palometa 222
Panulirus 114, 117
papagallo 219
Paralabrax 16, 225
Paralichthys 296
parallelism 71
Paranthus 232
parasitism 35, 39, 115, 132–133
Parexocoetus 199

pargo 235–238
parrotfish 16, 53, 258–260, *260*
Patella 120
peacock tail *82*, 83
pearlfish 38, *129*, 291, *291*
pêche prêtre 273
Pecten 123, 124, 294
Pediculati 299–302
pegador 282
Pelagia 99
pelagic subprovince *10*, 18, 19–20
Pelagophycus 80, 83
Pelagothuria 128
Pelamis 309
Pelecypoda 122–124
Peneus 114
Penicillus 79, 80, *129*
Pennaria 95, *98*
Pennatula 96, 103
Peprilus 221
Percesosces 202–206
perch *224*, 225, 247, *247;* surf 17, 252, *252*
Percoidei 222–251
periwinkle 21, *120*, 121
permit 217
pescado azul 253
pescados del rey 203
peto 210
Petrometopon 231, 232
Petromyzon 134
Phaeophyta 80–83
Phalacrocoridae 309
Phancrodon 252
Pharyngognathi 254–260
pharynx 109
Philonexis 123, 125
Phoca 313
Phocaena 321
phoebe 233
Pholis 288
Phoronis 105, 107
phosphorus 3
Photocorynus 39
photography 53–39
photosynthesis 4, 5, 6, 7, 33, 76, 78, 80, 83
Phycis 294
Phyllopteryx 201
Physalia 99, 221
Physeter 318
picuda 204
pigfish 242
pike 196–197, 223
pilchard 72
pilot fish 214, *214*
Pimelometopon pulcher 256
pinfish 245
Pinna 123, 124
Pinnipedia 311–314
pintado 210
pipefish 22, 45, 201
plankton 6, 7, 9, 17, 18, 19, 20, 32, 33, 34–37, 64
Platichthys 296
Platophrys 298, *298*
Platyhelminthes 104–105
Platyrhinoidis 165
Plectognathi 64, 266–267
Pleurobranchia 104, *104*
Pleuronectes 296
Pleurotremata 139–161
Pneumatophorus 209
Poecilidae 196–197
Pogonias 249
poison 34, 64, 100, 122, 124, 125, 129, 169, 176, 195, 270, 272, 308
polka dot 231
Pollachius 293
pollack 293
Polychaeta 108–111
Polychoerus 105, *105*
polyclad 105, *105*
Polynemus 206
polyp 93–104, 96
Polysiphonia 84, 85
Pomacanthus 262, 263, *264*
Pomacentrus 262
Pomadasis 240
Pomatomus 219
pomfret 222
pompanito 217
pompano 73, 216, 217, *217*, 222
pompon 242
population 68
porcupine fish 43, 64, 271
pore cell 47
porgy 16, 242–245, *243*
Porichthys 285
Porifera 47, 90–93
porkfish 41, 241
Poronotus 221
Porphyra 84, 85
porpoise 66, 67, 71, 315, 318–321, *319*
Portuguese man-of-war 19, 22, 38, 43, 63, 94, 99, 129, 306
Postelsia 80, 83
prawn *114*, 116
pressure 5–6
Priacanthus 235
priestfish 273, *273*
Prionace 141, 154
Prionodes 42, 233, *233*, 234
Prionotus 278
Pristis 164
prochordates 18, 126, 130, 131
Promicrops 227
Protococcus 78
Protozoa 19, 86–90
province 15; benthic *10*, 18; neritic *10*, 18, 20–22; oceanic *10*, 18, 20–22; pelagic *10*, 18
Pseudoceros 105
Pseudopleuronectes 297
pseudopodia *88*, 89
Pseudopriacanthus 235
Pseudoscarus 259
Psolus 128
Pteria 123
Pterognathus 288
Pterois 272
pteropod 18, 19, 20, 122, *123*
puffer 34, 64, 270–271
purple sail *96*, 99
pycnogonid 118–119

queenfish 248

rabbitfish 270
rabirubia 237, 238
Rabirubia 238
race, human 69
rachiglossan 121
Rachycentron 220
radiolarian 18, *88*, 89
radula 119, 121, 122
Raja 136, 139, 165, 166–167
ratfish 176, *176*
ray 20, 21, 41, 44, 161–176; anatomy *136;* butterfly 172, *172;* cow-nosed *173*, 174; eagle 63, 136, 139, 173–174, *173;* electric 167–169; evolution of 161–162; manta 34, 53, 175, 220; round sting 40, 43, *170*, 171; sting 63, *162*, 169, *170*, 171–172; torpedo 168, *168*

razorfish 257, *257*
red fish 249, 256
red tai 243
red tide 63, 88
reef, atoll 24, *25;* barrier 24, *25;* fringing 24, *25*
reef fish 254, *255*
regeneration (see autotomy) 89, 104–105
remora, shark 282, *282*
Renilla 93, 106
repellent, shark 142
Reptilia 303–309
respiratory system, 108, 112, 122, 137, 304
rhabdocoel 105, *105*
Rhacochilus 252
Rhegnopteri 205–206
Rhineodon 150
Rhinobatoidea 164–165
Rhinobatos 164
Rhinoptera 174
Rhizophora 22
Rhizopoda 89
rhizostome 99–100
Rhodophyta 83–85, *85*
Rhodymenia 84, 85
ribbonfish 19, *42,* 251
Rissola 291
robalo 223
Roccus 225
rock beauty 263
rock cod 273
rockfish 17, 225, 229, 230, 272–275
rockling 294
rock trout 275
rockweed 21, 80, *82*
Roncador 249, 250
ronco 72, 238–242, *241*
roosterfish *218,* 219
rosefish 273
Rossia 123
Rotifera 106, *106*
rudderfish 215, 246
runner 44, 214, 216
Rypticus 233

sabalo 181
Sabellidae 111
Sacculina 113, 115
Sagitta 105, 106
sailfish 39, 44, 212, *212*
sailor's choice 240, 241, 242, 245
sailor's purse 165
salema 244
salinity 3, 14, 32
Salmo 187–188
salmon 187–188, *187, 188*
salmon herring 184
Salpa 131
salts 3–4
sand bug 21, 116; dab 297, *297;* dollar 127–128, *128;* fish 233, 282, *283;* launce 206–207, *206*
Sarcodina 89
Sarda 210
sardine 72, 184, 185
Sardinella 185
sardinera 230
Sargasso Sea 7, 12, 13, 22–23, 191, 192
sargasso weed 1, 21, 45, 80, *80,* 83, 268
Sargassum 22, *80,* 83
sargassum fish 1, 23, 45, 301
sargo 242, 245
saurel 215
saury 198–199
sawfish 65, *163,* 163–164
scabbard fish 211
scad, *214,* 215
scale, placoid 136
scallop 48, 49, *123,* 124, 294
scaly-fin fishes 261–265
scamp 229
Scaphopoda 122
Scarus 259, *260*
scattering 53–54
Schilbeodes 195
schistosome 104, *105*
schoolmaster 236
Sciaena 249, 250
Sciaenops 249
scissors 198–199
Sclerodermi 266
Scoliodon 156, 157
Scomber 209
Scomberesocidae 198–199
Scomberomorus 209, 210, 220
Scorpaena 274, 275
Scorpaenichthys 276
scorpion fish 40, 41, 45, 63, 272–275, 274
sculpin 17, 40, 43, 275, 276–277, *277*
scungill *120,* 121
scup 243
Scyliorhinus 146
Scyllis 108, 109
Scyphozoa 99–100
sea, origin of 26; and plasma 27; size of 2
sea basses 223–234; beaver 310; colander *82,* 83; cow 314, *314;* cucumber *128,* 130; fan *101,* 102; feather *96,* 103, 130, *193;* gooseberry 104, *104;* hare 122; horse 22, 45, 201–202; lettuce 78, *79;* lily 130; lion 66, 311–313, *312;* moss 38, 78, *79, 84,* 85; mouse *108,* 109; otter 83, 309, 310, *310,* 321; palm *80,* 83; pansy *96,* 103; pen 100, 103; plume 102, *264;* pumpkin *80,* 83; purse 165; raven 277; robin 278–279, *278;* serpent 192; slug 34, 40, 43, 44, 46, 91, 122; snail 17; spider 23, 91, 118, *118;* squab 266; squirt 18, 119, 131; strider *118;* toad 299; turtle 32, 66, 282, 304–308; trout 247–248, *248,* 275; urchin 21, 22, 47, 63, 66, 127–129, *128;* walnut 104, *104;* wasp *96,* 99; weed 76–85; whip *98,* 102, *193*
seabather's eruption 104
seal 35, 66, 309, 311–314, *313, 314*
Sebastodes 17, 273–274
selection (see evolution 68–73), 29
Selene 218
sennet 204
señorita 257
senses (see behavior 46–52) 138, 179
Sepia 44, 125
Sepioteuthis 126
sergeant fish 220, 223
sergeant major 43, 253
Seriola 213, 214, 215
Seriphus 248
Serranidae 223–234
serraño 234
shad 185, 245
shadow elimination 41
shagreen 136
shark 51, 64, 139–161; angel 160–161; basking 19, 34, 66, *149,* 149–150; bay 156; black-tipped 141, 155; blue 141, 154, *154;* bone 149; bonito 148; bonnet *158,* 158–159; brown 156; bull 155; cat 146–147; comb-toothed 144; cow 144, *144;* cub 155; fox 151; frilled 19; Greenland 160; griset 144; ground 141, 155–156, *156;* gurry 160; hammerhead 139, 141, 158–159, 319; horned 144; Lake Nicaragua 155; lemon 141, 155; leopard 141, 142, 152, *153;* mackerel 139, 140, 147–149; mako *41,* 141, 147, *148;* man-eater 140, 148; mud 144;

nurse *137*, 145, *145;* oil 157; perlo 145; porbeagle 148; Port Jackson 136, *143*, 144; requiem 152–158; sand 141, *146*, 147; sandbar 156; seven-gilled 145; sharp-nosed 156, *157;* six-gilled 64, 144; sleeper 160; soup-fin 157, *157;* swell 146, *146;* thresher 150–151, *151;* tiger *137*, 139, 140, 141, 153, *153*, 319; whale 34, 53, 66, 150, *150;* white 36, 140, 148, *148;* white-tipped 156; yellow *154*, 155
shark sucker 44
sheepshead 244, 245, 256
shell *120*, 121–122, 124, *124*
shellfish 269
shore 21–22; slater *113*
shrimp 23, *113*, 116, 117
sierra, Mexican 210
silicon 4
Siluridae 195–196
silver fish 211
silver king 181
silversides 186, 202–203, *203*
singing fish 285
Siphonophora 18, 99
Sipunculida 111
Sipunculus 108
Sirenia 314
size, and danger 66; and refraction 56
skate 136, 139, 165–167, *165*, 172
skipjack 198, *205*, 210, 216
sleeper 281
slippery dick 255, 257, *257*, 291, *291*
smell (see behavior 46–52) *48*
smelt 188–189, *189*, 202
smoothhound 152
snail 18, 21, 22, 23, 48–49, 63, *120*, 121–122
snake, sea 63, 308–309, *309*
snakefish 190, *190*
snapper 22, 39, 235–238
snook 223, *223*
soapfish, two-spined *232*, 233
Solaster 128
soldier fish 207
sole 45, 295, 297, 298–299, *299*
Solea 45
Somniosus 160
spadefish 261
Spanish flag 274
Sparisoma 258–259
Spartina 21
spearfishes 65, 66, 211–213
species 27, 30, 69, 73–74
Sphenodon 303
Spheroides 270, 271
Sphyraena 204, 205, *205*
Sphyrna 158
spicule 63, 90, 91, *91*, 93
spines 63–64, 136, 265
Spondylus 123
sponge 18, 21, 32, 39, 47, 63, 83, 90–93, *91*, *92*, 119
sponge seaweed *79*, 80
spongin 90, 93
spot 245, 250
Squalus 159
Squamata 308–309
Squamipinnes 261–265
Squatina 160–161
squeteague 247–248, *248*
squid 18, 19, 20, 21, 43, 44, 48–49, *48*, 63, 66, *123*, 125–126, 318
Squilla 113, 117
squirrel fish 7, 32, 64, 207
starfish 17, 22, 47, 103, 122, 127, *128*, *129*, 130
stargazer 21, 40, 44, 283, *284*
Stenopus 114, 117
Stenorhynchus 45, *110*, 117
Stenotomus 243
Stereolepis 227, 228
stickleback, two-spined 200, *200*
stingaree 171, *171*
stonefish 272
strobilation *96*, 99
Strombus 121
Stromeidae 221–222
Strongylura 198
sturgeon 72, 180, *180*
subarctic *15*, 17
subtropics *15*, 15–16
suckfish 282
suctorian *88*, 90
support (see buoyancy and flotation) 2, 20
surf fishes 251–252
surgeonfish 265
surmullet 207–208
swell toad 271
swim bladder 6, 18–19, 178
swimmer's itch 63, 104
swordfish 212–213, 321
Sycon 47
symbiosis 25, 37–39, 89, 91, 103, 117
Symphurus 299
Synanceja 272
Synentognathi 197–199
Syngnathus 201
Synodus 190

taenioglossan 121
Taeniotoca 252
tambor 273
tang 44, 255, 265
taste (see behavior 46–52)
tattler 223
tarpon 22, 40, 65, 66, *181*, 181–182
Tarpon 181
tautog 255, *256*
Tautoga 255
Tautogolabrus 256
taylor 219
Tedania 91, 93
teeth 64, 136, *137*, 163
Teleostei 180–302
temperate seas *15*, 16–17
temperature 6, 8, 9, 14, 15–17, 23, 32
tenpounder *182*, 182–183
Terebratulina 123
Teredo 124
territoriality 33
Testudinata 302–308
Tetraodon 266
Thalassia 76, *129*, 185
Thalassoma 257
thermocline 9
thornback 165
threadfin 205–206, *206*
threadfish 219
Thunnus 210
tide 11–12
tidepool 21
tilefish 283
toad 302
toadfish 40, 43, 64, 65, 284–285, *285*
tomcod 293, 294
tom tate 239, 240
tonguefish 299, *299*
tope 157
Torpedo 168
tottuava 248
touch (see behavior 46–52)
toxoglossan 121
Trachinocephalus 190, *190*

Trachinotus 216–217
Trachinus 44, 45
Trachurops 215
Trachurus 215
trachyline hydrozoa 95
trade winds 12
treefish 274, *274*
trench, oceanic 10, *10*
Triakis 141, 142, 152
Trichechus 315
Trichiurus 211
Trichodesmium 78
triclad 105, *105*
triggerfish 64, *264*, 266–267
Triglidae 278
tripletail 234
tropic bird 309
tropics *15*, 15–16
trout 187–188
trumpetfish 45, 193, 200
trunkfish 268, *269*, 270
Tubularia 95, *96*
tuna 32, 66, 210
Tunicata 19, 21, 23, 131
turbellarian 104–105
turbot 267, 295, 297–298
Turitella 120
Tursiops 318
turtle 32–33, 35, 73, 302–308, *305*, *306*, *307*, *308*
turtle grass 76, 85, *129*

Uca 114
Ulva 78, *79*
Umbrina 249, 250
Upeneus 207–208
upwelling 3, 4, 5, 13–14, 16, 17, 23
Uranoscopidae 283
Urobatis 171
Urolophus 139, 171
Urosalpinx 120, 121

vagility 32
valence 30, 31, *31*
vaqueta de dos colores 263
Velella 96, 99
Venus 123, 124
Venus flower basket *91*, 93
Venus girdle 104, *104*
Vermetus 120
Verrunculus 267
vertebrate, definition 132
vieja 259
viperfish 187
viscosity 4, 9, 19
vision (see behavior 46–52) 40
viviparous 139
Vomer 218

wahoo 65
walrus 309, 311
water 2, 4, 6, 7, 8, 9, 19, 53; currents 12–14, *13*
water striders 119
waves, light 7; oceanic 11, *12*
weakfish 247, 248
Weberian apparatus 195
westerlies 12
whale 30, 32, 34, 66, 309, 315; blue 34, 316, *317;* bowhead 317; California gray 317, *317;* finback 316; humpback 317; killer 34, 35, 36, 64, 65, 149, 317, 318, *319*, 321; ridge-throated 316; right 317, *317;* rorqual 316; sperm 31, 34, 125, *317*, 318; sulfur-bottom 316
whalebone 316–317
whelk 21, 121
whiff 298
whitebait 189, 202, 203
whitefish, ocean 283
whitey 282
whiting 250–251, *251*, 292
wind 11, 13
worm 4, 8, 18, 19, 21, 22, 23; acorn 130; arrow 18, 21, *105*, 106; bristle 63, *108*, 109; budding *108;* burrowing 110–111; errant 109–111; fan 111; flat 105, *105;* lug 111; marine 108–111; mounds *110;* palolo *108*, 109; parchment *108*, 111; phoronid *105*, 107; ribbon 106; sand 48, 107, *108*, 109; scale *108*, 109; segmented 107–111; ship *123*, 124
wolf fish 65, 289, *289*
wrasse 53, *102*, 254–258
wry-mouth 289, *289*

Xanthichthys 267
Xenopterygi 284, 285–286
Xestoleberis 113
Xiphias 212
xurel de castilla 216
Xyrichthys 258

yellow belly 253

Zalophus 312, *312*
zapatero 213
Zapteryx 165
Zoarces 290
zone, definition 14; geologic 9–10, *10;* light 7, 8, 18; mangrove 22; nitrogen 3; phosphorus 3; substrate *10*, 17–25; temperature *15*, 15–17
zoochlorellae 89, 94, 100, 103, 105
zooxanthellae 38, 89, 94, 100
Zostera 76, 85, 305